United States
Environmental Protection
Agency

Office of
Policy Analysis
Washington, DC 20460

EPA-230-11-85-017

Water

EPA

A Methodological Approach to an Economic Analysis of the Beneficial Outcomes of Water Quality Improvements from Sewage Treatment Plant Upgrading and Combined Sewer Overflow Controls

Environmental Benefits Analysis Series

A Methodological Approach to an Economic Analysis of the Beneficial Outcomes of Water Quality Improvements from Sewage Treatment Plant Upgrading and Combined Sewer Overflow Controls

Prepared for

Office of Policy Analysis
U.S. Environmental Protection Agency
Washington, D.C.

by

Meta Systems Inc
10 Holworthy Street
Cambridge, Massachusetts 02138

Preface

This report is submitted by Meta Systems Inc in fulfillment of EPA contract #68-01-6596 700-E. This report estimates the benefits and costs of upgrading two sewage treatment plants and of constructing combined sewer overflow controls in the Boston Harbor area.

We are grateful for the review and comments of Clark Binkley, Yale University; A. Myrick Freeman, Bowdoin College; and Leon Abbas, North Carolina State University. We wish to give special thanks to the following people who provided technical assistance and/or data for the study:

Peter Harrington--Massachusetts Department of Environmental Quality Engineering;

Michael Hickey and David Chadwick--Massachusetts Division of Marine Fisheries;

Jean M. Haggerty, Al Ferullo, and Paul DiPetro--Metropolitan District Commission;

F. Williams Sieling, Mark M. Bundy, and Christopher Bonzack--Maryland Department of Natural Resources;

Dana Wallace--Maine Department of Marine Resources;

While we are indebted to all of the above for their contributions, final responsibility for the analysis, results and conclusions rests solely with the authors.

Table of Contents

Table of Contents
(continued)

Table of Contents
(continued)

Table of Contents
(continued)

List of Tables and Figures

List of Tables and Figures
(continued)

List of Tables and Figures
(continued)

List of Tables and Figures
(continued)

Section 1
Summary and Conclusions

The purpose of this project is to determine the feasibility and usefulness of an economic analysis of the beneficial outcomes of water quality improvements that should result from upgrading sewage treatments plants (STPs) and from combined sewer overflow (CSO) controls. This report uses Boston Harbor, Boston, Massachusetts, to serve as a case study which demonstrates the application of a variety of benefit estimation techniques in order to develop a range of benefit values associated with the uses of the Harbor which would be affected by the various pollution control treatment alternatives. It contains pertinent data and computations to demonstrate the application of the techniques. This report may also serve as an Appendix to the EPA's Marine CSO Handbook, which states can use as an example of how to perform benefit analysis. Where feasible, the study provides dollar estimates of the economic benefits of the treatment alternatives for the two primary benefit categories (recreation and commercial fishing) as well as for other relevant benefits.

The STP treatment options considered here include upgrading from primary to secondary treatment and upgrading the existing primary treatment with an ocean outfall. One of the STP options considered follows from the legal mandate of the 1972 and 1977 Clean Water Act and Amendments, the Environmental

Protection Agency (EPA) standards and procedures for the treatment and disposal of municipal wastes. These regulations call for treatment at the secondary level (which includes more BOD and SS removal in addition to basic primary treatment) and a cessation of sludge disposal in the ocean.

The second STP option is an ocean outfall in conjunction with upgrading existing primary facilities. Plans have been made by the Metropitan District Commission (MDC) to repair and rehabilitate the STPs so that they will function properly at an upgraded primary treatment level. In addition, the MDC has applied for a variance under section 301(h) of the Clean Water Act from secondary treatment requirements. The application is based on an improved discharge whereby the two existing plants will improve their operation of primary treatment, and effluent will be discharged at an ocean outfall in Massachusetts Bay via a tunnel 12.1 km (7.5 miles) from Boston Harbor. Since the initiation of this study, the proposed ocean outfall has been tentatively denied by the EPA Administrator (in June, 1983).

The selection of these options does not constitute endorsement of these proposals over other STP options, nor is this study a part of the formal 301(h) evaluation efforts. Rather, since the purpose of this study is to determine the feasibility and usefulness of an economic analysis of the beneficial outcomes of improved water quality, the two STP options are analyzed here as representative of the options under consideration at the time the study was initiated.

The CSO control options are derived from studies done for the Massachusetts District Commission as well as studies done for the town of

Quincy. They include control of pollution due to combined sewer overflows, stormwater discharges and dry weather overflows all of which contribute significantly to the CSO problems in the Boston Harbor area.

Boston Harbor is surrounded by a major urban center and, despite its serious water quality problems, provides the setting for many and diverse water uses including a fishing and shipping port, recreational boating, swimming and beach activities, shellfishing, finfishing, and, especially recognized in recent years, an aesthetic focal point for commercial, residential and recreational activities. Figure 1-1 shows the geographic features of the study area.

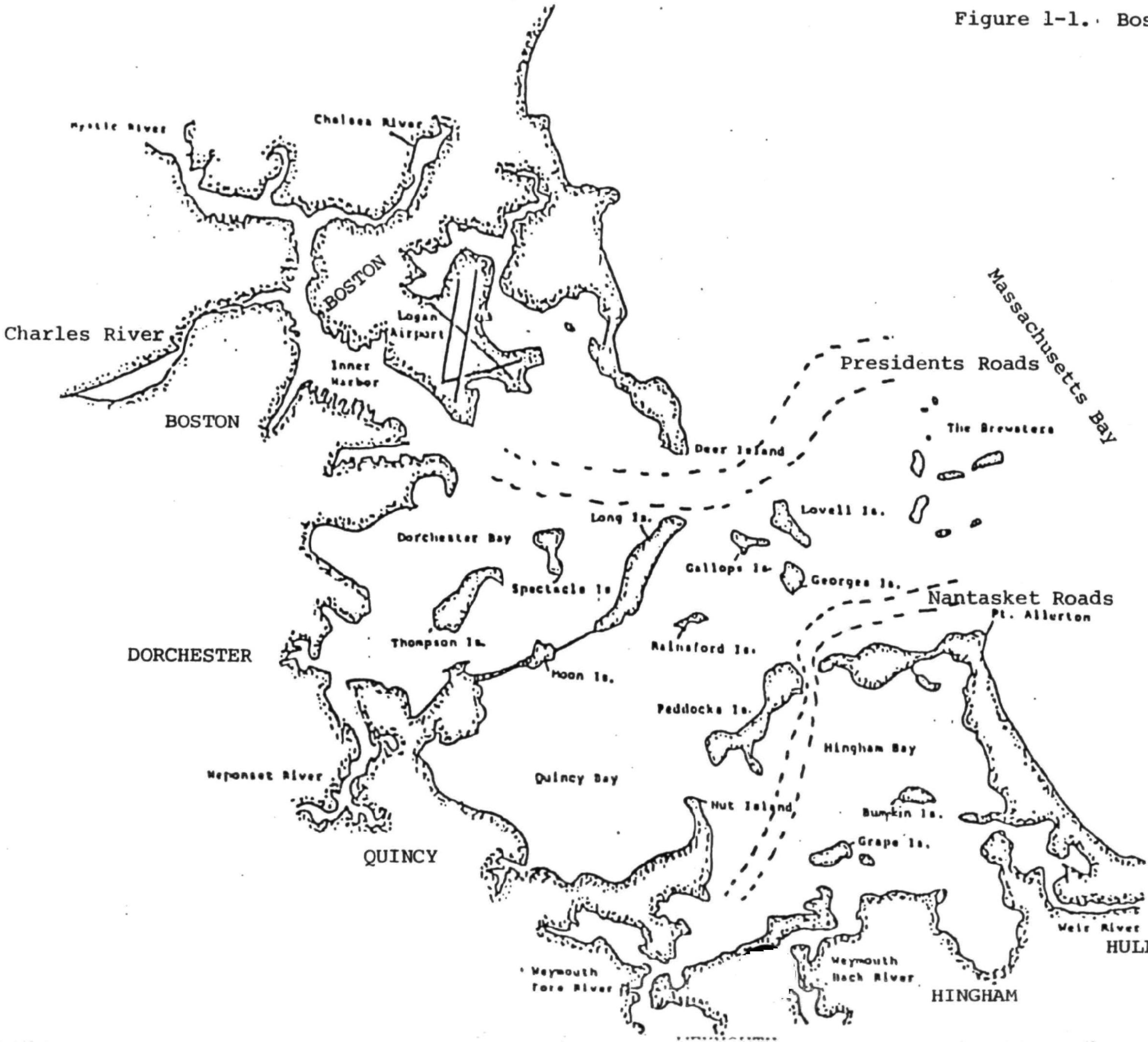
Due to the complexity of the situation, the constraints of the data, and the evolving nature of benefits analysis the results of this study should be viewed with caution. Every effort is made to assess the reliability of both the data and methods used. In the individual chapters of the report specific sections on the limitations of the analysis are provided.

This chapter provides a brief overview of the treatment alternatives, receptors, benefit categories, and benefit methodologies. A comparison of the benefits and costs of the alternatives is presented and the results of the study summarized.

1.1 Pollution Sources

Two major sources of pollutant loadings to Boston Harbor are 1) the Nut Island and Deer Island Sewage Treatment Plants (STPs), owned and operated by

Figure 1-1. Boston Harbor Study Area

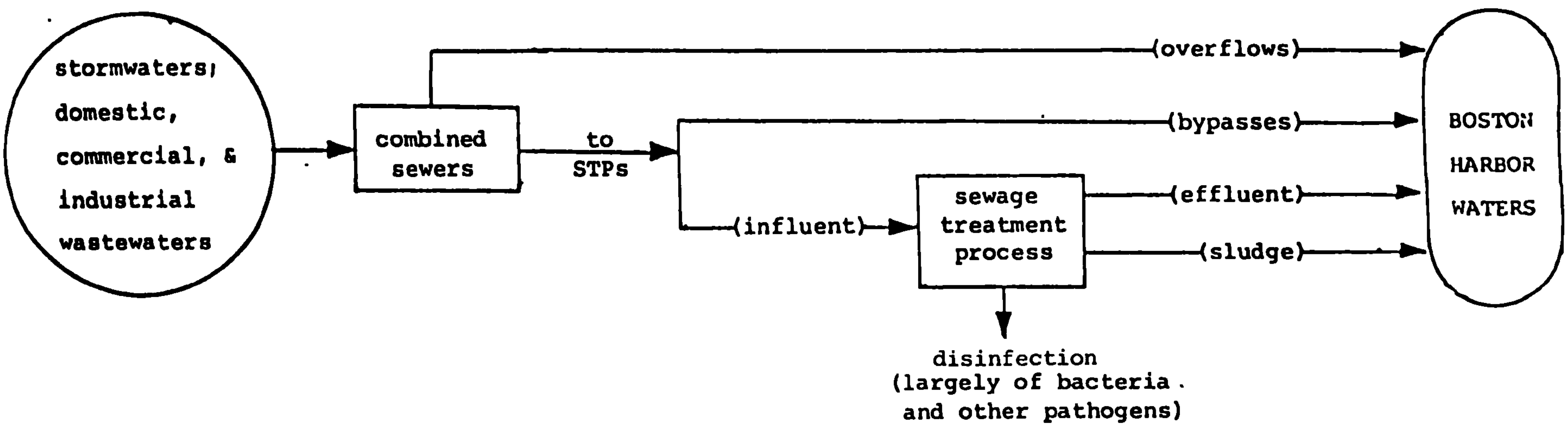


the Massachusetts Metropolitan District Commission (MDC), and 2) the combined sewer overflows (CSOs) located along the Harbor shoreline. The pollutants which are released from these sources serve as parameters for describing the environmental condition of the waters of Boston Harbor. Figure 1-2 is a schematic presentation of how the pollutant loadings enter the harbor from these sources. The following water quality parameters are considered in this report:

Parameter	Reason for Consideration
Coliform (fecal and/or total)	important criteria for swimming and shellfishing needs; indicator of domestic sewage pollution
BOD (biochemical oxygen demand); SS (suspended solids); oil and grease	conventional pollutants; standard wastewater characteristics
Heavy metals and toxics (copper, mercury, nickel, etc.)	potentially dangerous to aquatic life

Once these pollutants are released into the Harbor, they mix with ambient waters, and can seriously compromise water quality and, consequently, adversely affect the ecological habitat, recreation, aesthetic, and commercial fishing activities, and personal health. The heavy metals and other toxic pollutants affect the functioning of Harbor marshlands and influence the abundance and diversity of shellfish and finfish in the waters. The mechanisms and effects as related to levels of pollutant control are not known, however. Thus, this report presents information on current loadings of toxic pollutants from the STPs and qualitatively describes the ecological habitat and potential effects for these pollutants.

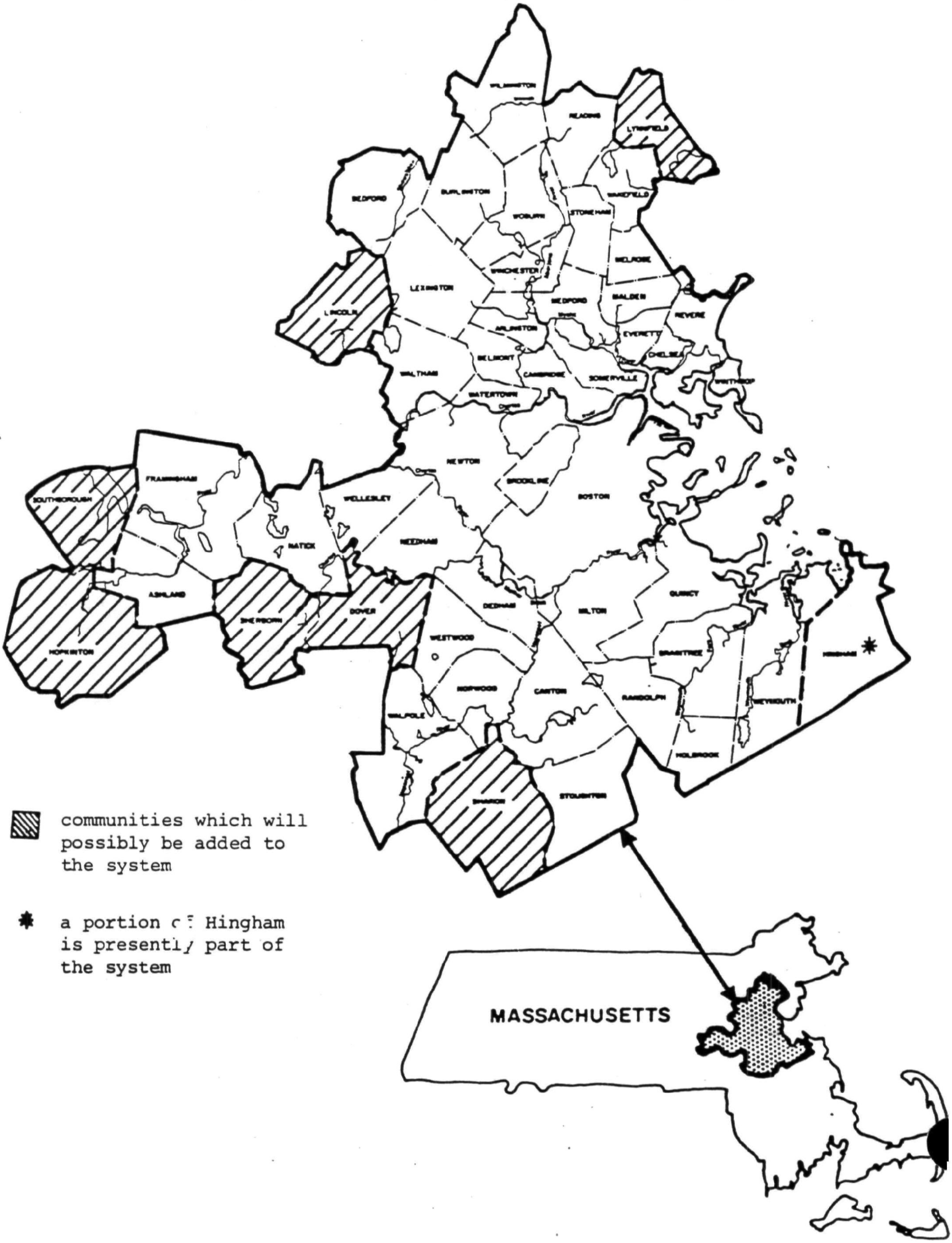
Figure 1-2. Schematic of Sources of Pollutant Loadings to Boston Harbor



Forty-three towns and cities in the Boston Metropolitan area belong to the Metropolitan Sewage System and send their domestic, commercial and industrial wastewater to the two sewage treatment plants for treatment and disposal (see Figure 1-3). At present, both plants are designed to carry out primary treatment which is essentially a screening, sedimentation and chlorination procedure. The treated effluent and concentrated, digested sludges are then discharged into the Harbor. System malfunctions are common, however, resulting from such factors as outfall pipe deterioration, inadequate holding capacity and lack of normal required maintenance due to, among other things, difficulties in obtaining funds for repairs and suitable replacements for malfunctioning components. As a result, the two STPs have not been functioning properly in accordance with their designs, leading to raw sewage bypassess directly into the Harbor, improperly timed sludge releases, sewer backups from the STPs, and less than design-level treatment performance, all of which adversely affect water quality.

The two STP options consist of secondary treatment and upgraded primary treatment with an ocean outfall. The secondary treatment option includes more BOD and SS removal than the current primary treatment facilities and a cessation of sludge disposal in the ocean. The ocean outfall option includes repair and rehabilitation of the existing primary treatment facilities and discharge of the treated effluent into Massachusetts Bay by way of a tunnel from Deer Island. These two options were picked from the many proposals being studied at the time of this report as representative of the proposals and not as an endorsement of one proposal over another.

Figure 1-3. Area Served by the MDC Sewerage System



communities which will possibly be added to the system

✱ a portion of Hingham is presently part of the system

Table 1-1 compares the annual costs of the STP options and shows very approximate percentages for reductions in effluent pollutants, including BOD_5, suspended solids (SS), and metals, over existing concentrations.

In its effort to develop a comprehensive plan for CSO control in Boston Harbor, the MDC has designated four CSO planning areas: 1) Dorchester Bay, 2) Neponset River, 3) Inner Harbor (including Constitution Beach) and 4) Charles River Basin. The four areas are defined on the basis of existing water use and coastal use patterns. The water quality of all four planning areas is compromised by pollution from combined sewer overflows (CSOs), stormwater discharges, and dry weather overflows (DWOs). Storm-related combined sewer overflows vary in duration and frequency. DWOs, caused by sewer blockages and other malfunctions, are continual discharges of sanitary wastewater and are considered by the MDC to be the single most important source of pollution in Boston Harbor. They have thus been included in all the CSO plans even though they are not officially classified as CSOs under federal regulations. Combined sewer overflow outlet locations are shown in Figure 1-4.

Another source of pollutant loadings to Boston Harbor is the Quincy storm sewers. The Quincy storm sewers discharge waters with fecal coliform, BOD and SS concentrations that are higher than levels expected from storm water runoff. Storm water contamination can result from cross-connections between sanitary and storm drains, due to broken pipes and exfiltration from sanitary sewers in disrepair, and, possibly, illegal "tie-ins" to the storm sewer system although the latter has not been documented in Quincy. These present problems similar to the DWOs in Boston which have been included in the CSO plans. The Quincy storm sewers lie outside the MDC study area of

Table 1-1. Costs and Potential Reductions in STP Effluent Pollutants for the STP Options (Millions 1982$)

Wastewater Treatment STP Options	Costs			Approximate Percentage Reduction in Effluent Pollutants b/
	Annualized Capital Cost a/	Annual O&M Cost	Total Annual Cost	
Upgraded Primary With Ocean Outfall	74.9	22.0	96.9	c/
Secondary	85.8	45.2	131.0	60 - 80

a/ Based on 8 1/8 percent interest; 20 year period.

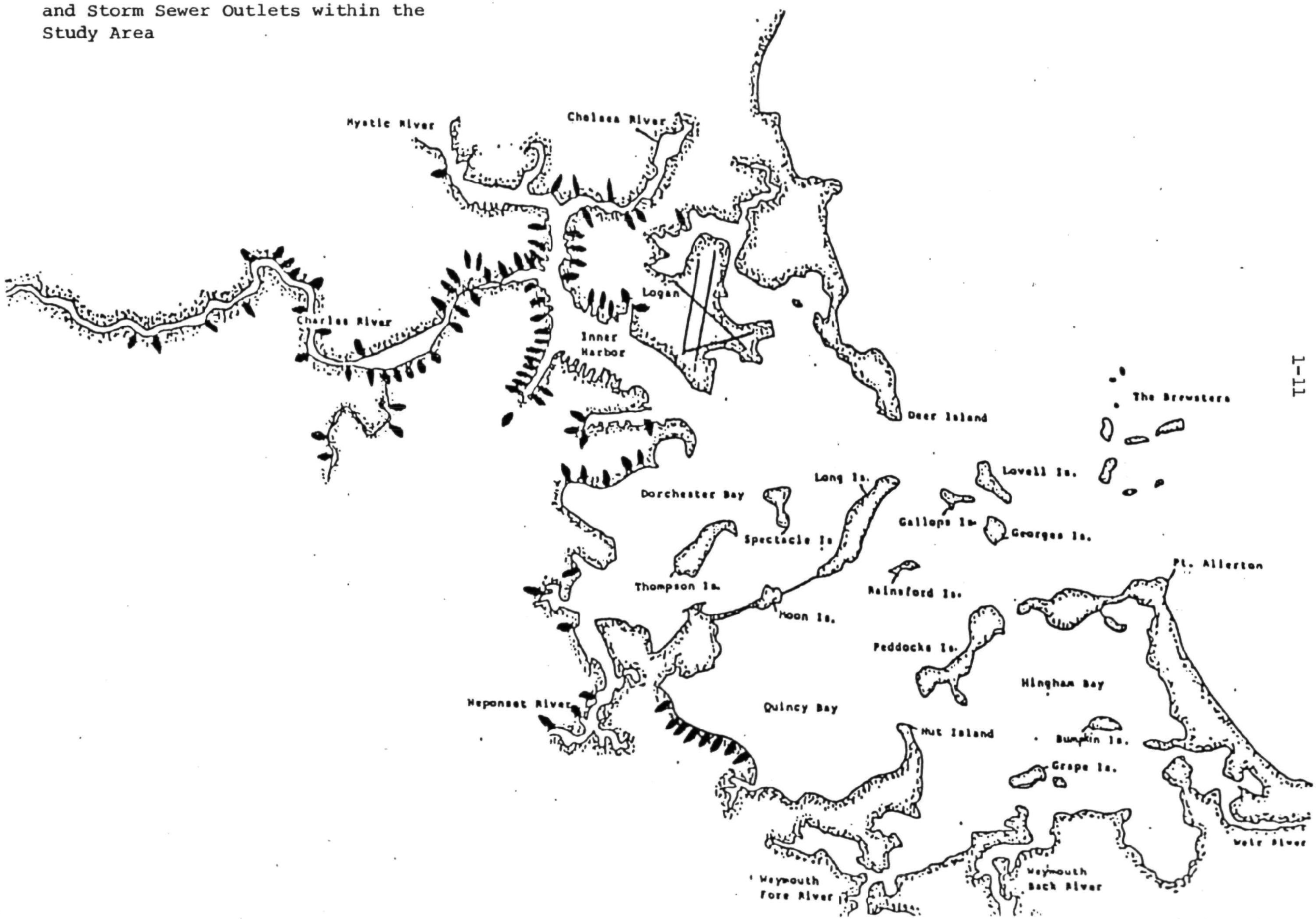
b/ Average potential reductions in effluent pollutants (BOD_5, SS and metals) over existing concentrations. Range is a very approximate estimate. For four heavy metals (cadmium, chromium, lead, mercury) the reduction would be about 30%.

c/ No effluent will be discharged in Boston Harbor. There will be increases of pollutants in Massachusetts Bay, however. See Section 4 for details.

Source: See Tables 2-2 and 2-3, Section 2.

Figure 1-4

Location of Combined Sewer Overflow and Storm Sewer Outlets within the Study Area



concentrated CSOs. However, they have been included as an option for this benefit-cost study because they have a significant adverse impact on the water quality of Quincy's town beaches and Wollaston Beach, a large MDC operated beach attracting many visitors, located in Quincy.

Table 1-2 shows the annual costs of the CSO options along with the approximate percentage reduction in pollutant loadings, including fecal coliform, floatable and suspended solids and oil and grease. The top part of the table presents the four CSO plans as designated by the MDC. The bottom part shows the options used in the benefit-cost analyses in this study (for a detailed discussion of the CSO options see Section 3). The options as defined in the lower half of the table correspond more appropriately with the benefit estimates associated with the uses of the Harbor. For example, all the swimming and shellfishing uses affected by the CSOs (and therefore the corresponding benefits estimates) can be captured by including only the Constitution Beach portion of the Inner Harbor Plan plus the Dorchester Bay, Neponset River, and Quincy Bay Plans. The CSO options in the table reflect incremental increases in annual costs.

1.2 Water Quality

Currently, the CSOs and STPs jointly affect some of the same harbor areas (see Figure 1-5). However, the CSOs generally affect the areas closest to the shore including the shoreline swimming beaches and fishing and boating areas near the shore. In comparison, the STPs have the greatest impact on water surrounding the STP outfalls and thus mostly influence the central parts of the harbor, particularly the Boston Harbor Islands. Beaches in the towns of Quincy, Weymouth, Hingham and Hull are also affected.

Table 1-2. Incremental Costs and Potential Reductions

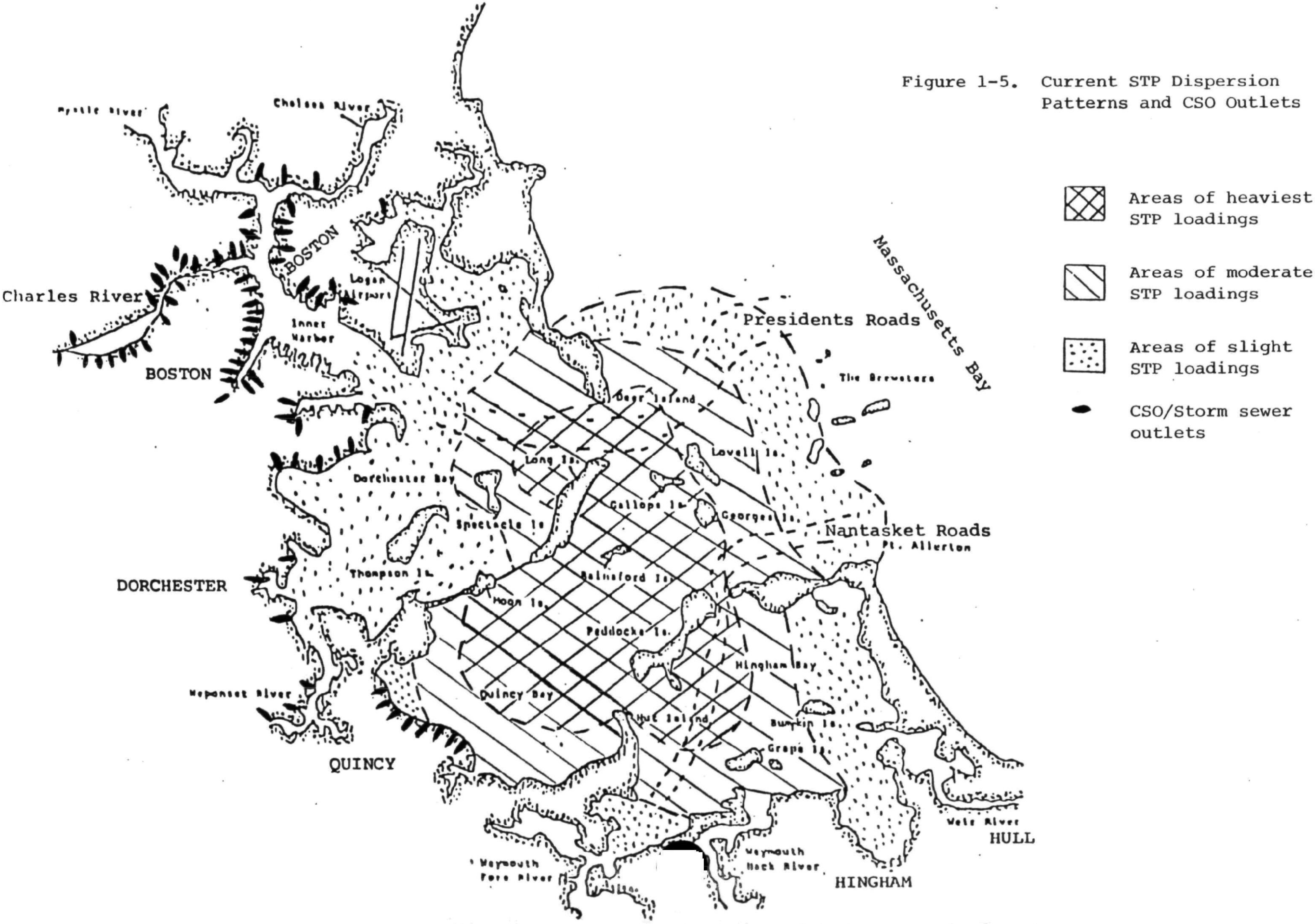
in Pollutant Loadings for the CSO Options

(Millions 1982$)

Treatment Alternative/ Receptor	Annualized Capital Cost a/	Annual O&M Cost	Total Annual Cost	Percentage Reduction in Pollutant Loadings b/
MDC PLANNING AREA DESIGNATION				
Inner Harbor				
a) Including Constitution	14.63	1.97	16.61	
b) Constitution only	0.04	0.01	0.05	50 - 99
Dorchester Bay	4.97	0.37	5.34	70 - 99
Neponset River	0.61	0.10	0.71	60 - 98
Charles River Basin	8.87	1.56	10.43	65 - 100
Implementation of all MDC designated CSO plans	35.44	4.00	33.39	50 - 100
STUDY AREA DESIGNATION				
Inner Harbor Constitution Beach only	0.04	0.01	0.05	50 - 99
Dorchester Bay/ Neponset River	5.59	0.47	6.06	60 - 99
Quincy Storm Sewers c/	0.27	-.02	0.25	60 - 99 d/
Above three plans combined	5.90	0.46	6.36	50 - 99
Charles River	8.87	1.56	10.43	65 - 100

a/ Based on 8 1/8 percent interest; 20 year period.
b/ From Contractor reports.
c/ Quincy plan is currently undergoing extensive revision.
d/ Assumed to be the same as Dorchester Bay Area.

Figure 1-5. Current STP Dispersion Patterns and CSO Outlets



The various STP and CSO treatment options will reduce pollutant loadings to the Harbor waters. The change in ambient water quality at various locations throughout the Harbor will depend on the change in reduced loadings but also on the dispersion pattern in the Harbor from the point of discharge to the receptor areas where recreation, boating and fishing take place. Several water quality models were used in the various contractor reports delineating the STP and CSO options. We use the results of these models to predict improvement in water quality related to percent reduction in pollutant loadings for the different treatment options at each receptor point in the study area. (See Section 4.) These estimates are presented in Table 1-3. The accuracy of the water quality models depends on both the data and methodologies available. Complexities due to currents, tides and weather make the transport and fate of pollutant discharges difficult to model. The results currently available preclude estimation of absolute changes in water quality but the relative percentage changes, as shown in Table 1-3, are adequate for the benefit estimation procedures used in this study.

1.3 Benefit Categories and Receptors

The benefit categories for which benefit estimates have been computed in this study have been determined by those uses of Boston Harbor that are affected by the pollution sources discussed above (STPs and CSOs). A term often used to describe areas or uses which are adversely affected by pollution sources and which would benefit from pollution abatement options is "receptors." The receptors or benefit categories in this study include recreation activities such as swimming, boating and fishing, commercial finfishing and shellfishing, the ecological habitat of the harbor and non-users who would be willing to pay, nonetheless, for pollution control

Table 1-3. Estimated Water Quality Impacts of the STP and CSO Treatment Options

Receptor Area	Percent Pollution Reduction by Treatment Option		
	Combined Sewer Overflow/ Storm Sewer	Deep Ocean Outfall	Secondary Treatment
Constitution Beach	50 to 80	5 to 10	0 to 5
Dorchester Bay	60 to 90	10 to 25	5 to 15
Quincy Bay	60 to 90	10 to 20	10 to 20
Hingham Bay	--	15 to 40	15 to 40
Outer Harbor Islands	--	60 to 90	30 to 80
Brewsters Islands	--	-10 to -15	30 to 40
Nantasket Beach	--	-5 to -10	0 to 5
Massachusetts Bay	--	-35 to -45	15 to 20
Charles River	50 to 80	--	--

Note: Positive figures denote improved water quality. Negative figures denote degradation in water quality.

(intrinsic benefits). Alternative pollution control programs and the affected receptors are shown in Table 1-4.

The benefits of improved water quality resulting from implementation of pollution control options in Boston Harbor accrue to users and non-users alike, and are presented below with a summary discussion of specific benefit estimates. The techniques used in this report to measure benefits to society from implementation of pollution control plans are based on the theory of welfare economics and the concept of willingness to pay. This economic theory is founded on the principle that the "demand" for water quality is the sum or aggregate of how much individuals would be willing to pay to receive additional increments of improved water quality. Section 5 discusses the theoretical concepts, benefits categories and the various methodologies used to estimate benefit values for the different treatment alternatives.

1.4 Summary of Study Findings

A summary of annual benefits and costs for the different control scenarios is presented in Tables 1-5 through 1-7. The control scenarios include the MDC's recommended plans for CSO control and also the benefits of implementing CSO controls along with the STP options. The tables report the dollar estimates for the benefit categories and receptor areas for Boston Harbor. An indication of those benefits which were not monetizable in this economic analysis is also included to emphasize the full range of impact of these pollution sources and their consequent clean-up. One way to consider this potentially large non-monetizable portion from the point of view of the decision maker is an implicit evaluation of what they must be worth if it is decided to implement the controls by considering the difference between the

Table 1-4. Pollution Control Program and Receptors

Pollution Control Option	Predicted Percent Cleanup[a]	Receptors/Benefit Categories
STP		
Ocean Outfall	10 to 30	Beaches: Weymouth, Hingham, Hull Boating and Fishing Shellfishing Intrinsic and Ecological
	-40 to -10	Beaches: Nantasket, Brewsters Islands Boating and Fishing Intrinsic and Ecological
Secondary	5 to 30	Beaches: Constitution, Dorchester Bay, Quincy Bay, Hingham Bay Shellfishing Intrinsic and Ecological
	20 to 70	Recreation: Outer Harbor Islands Boating and Fishing Intrinsic and Ecological
CSO		
Inner Harbor (includes Constitution)	70	Beach: Constitution Boating and Fishing Shellfishing Intrinsic and Ecological
Dorchester Bay and Neponset River	80	Beaches: Castle Island, Pleasure Bay, Carson, Malibu, Tenean Boating and Fishing Shellfishing Intrinsic and Ecological
Quincy Storm Sewers	80	Beaches: Wollaston, Quincy Boating and Fishing Shellfishing Intrinsic and Ecological
Charles River	70	Boating Intrinsic

[a] See Tables 4-2 and 4-3.

Table 1-5. Annual Benefits and Costs of Combined Sewer Overflow Controls
(Millions 1982$)

Pollution Control Option		Benefit Estimates by Category: Swimming[b]	Recreational Boating	Recreational Fishing	Health[d]	Commercial Shell-Fishing[e]	Intrinsic[f]	Ecological	TOTAL	Total Annual Costs[g]
Combined Sewer Overflows										
Constitution Beach	Range:	0.91-1.36	Not available for this option since boating and fishing are only calculated harbor-wide for combined STP and CSO options.		.005-.077	0-.005	Based on total recreational benefits. Not available for this option since boating and fishing benefits are only calculated harbor-wide for combined STP and CSO options.	Cannot be quantified but includes value of highly productive saltmarshes in Boston Harbor. These marshes in turn support many species of fish and invertebrates as well as animals, shorebirds and waterfowl.	0.92-1.44	0.05[h]
	Moderate:	1.14			.041	.003			1.18	
Dorchester Bay/ Neponset River	Range:	6.21-9.29			.021-.317	.001-.009			6.23-9.62	6.06
	Moderate:	7.75			.169	.005			7.92	
Quincy Bay	Range:	5.29-7.91			.086-1.275	0-.004			5.38-9.19	0.25-6.06[i]
	Moderate:	6.60			.681	.002			7.28	
Hingham Bay	Range:	-0-			-0-	-0-			-0-	
	Moderate:									
Massachusetts Bay/ Nantasket	Range:	-0-			-0-	-0-			-0-	
	Moderate:									
Entire Harbor (not including Charles River)	Range:	12.05-18.0[c]			.124-1.716	.001-.018			12.18-19.73*	6.36-12.17[h/i]
	Moderate:	15.02			.92	.010			15.95	
Charles River	Range:	-0-	.05-.96	-0-	-0-	-0-	3.14-6.28*		3.19-7.24	10.43
	Moderate:		.51				4.71		5.22	
Four MDC CSO Plans (Constitution, Dorchester, Neponset, Charles River)	Range:	7.12-10.65	.05-.96		.027-.394	.001-.014	3.14-6.28*		10.34-18.3	16.54[h]
	Moderate:	8.89	.51		.21	.008	4.71		14.3	

a/ Moderate benefits represent best estimates except for those categories where best estimate is marked by *. Range includes high and low estimate.

b/ Swimming benefits based on conditional logit model. For Quincy, Hingham and Nantasket beaches, benefits from increased participation are added since logit model did not include these beaches. All benefits are derived using user day value from logit model.

c/ Includes general recreation benefits at Boston Harbor Islands.

d/ Health benefits for individual areas based on swimming; for entire harbor benefits based on shellfish consumption are also included.

e/ Commercial fishing benefits based on shellfishing; estimates for finfishing and lobstering not available.

f/ Intrinsic benefits based on 50 percent of all recreational benefits; except for Charles River, which includes willingness to pay for user and non-user values.

g/ Annualized capital costs (assuming 8 1/8 percent interest, 20-year period) plus annual operation and maintenance costs.

h/ Excludes cost of Inner Harbor CSO plan except for Constitution Beach portion; total annual cost of Inner Harbor CSO plan is $16.61 million.

i/ Cost estimates for Quincy storm sewers are still preliminary. High estimate is equivalent to costs for CSO control in Dorchester Bay.

Table 1-6. Annual Benefits and Costs of Combined Sewer Overflow Controls and Ocean Outfall Control Option (Millions 1982[g/])

Pollution Control Option		Swimming b/	Recreational Boating	Recreational Fishing	Health d/	Commercial Shell-Fishing e/	Intrinsic f/	Ecological	TOTAL	Total Annual Costs h/
Benefit Estimates by Category										
Combined Sewer Overflows and Ocean Outfall										
Constitution Beach	Range:	1.05-1.57			.008-.119			Potentially	1.06-1,69	
	Moderate:	1.31			.064			large	1.37	
								beneficial		
Dorchester Bay/	Range:	7.41-11.08			.032-.477			impact on	7.44-11.56	
Neponset River	Moderate:	9.25			.255			shoreline	9.51	
								saltmarshes		
Quincy Bay	Range:	6.24-9.33			.146-2.15			supporting	6.39-11.48	
	Moderate:	7.78			1.15			fish and	8.93	
								invertebrates		
Hingham Bay	Range:	.215-.322			.003-.039			as well as	.22-.36	
	Moderate:	.269			.021			animals,	.29	
								shorebirds,		
Massachusetts Bay	Range:				(-.011) to (-.169)			and waterfowl.	(-.78) to (-.94)	
Nantasket	Moderate:	(-.772)			(-.090)			But negative	(-.86)	
								impact on		
Entire Harbor	Range:	15.23-23.6 c/	5.39-12.13*	.30-7.91*	.189-2.67	.022-.124	10.1-21.8	Massachusetts	31.23-68.23*	103.3-
(not including	Moderate:	19.03	8.76	4.11	1.43	.064	15.9	Bay with its	49.29	109.1 h/ i/
Charles River)								finfish,		
								lobster,		
Charles River	Range:	-0-	.05-.96	-0-	-0-	-0-	3.14-6.28*	crab and	3.19-7.24	10.43
	Moderate:		.51				4.71	migratory	5.22	
								whales and other		
Four MDC CSO Plans	Range:							species.		
(Constitution,	Moderate:									
Dorchester, Neponset,										
Charles River)										

a/ Moderate benefits represent best estimates except for those categories where best estimate is marked by *. Range includes high and low estimate.

b/ Swimming benefits based on conditional logit model. For Quincy town beaches, benefits from increased participation are added since logit model did not include these beaches. All benefits are derived using user day values from logit model.

c/ Includes general recreation benefits at Boston Harbor Islands.

d/ Health benefits for individual areas based on swimming; for entire harbor benefits based on shellfish consumption are also included.

e/ Commercial fishing benefits based on shellfishing; estimates for finfishing and lobstering not available.

f/ Intrinsic benefits based on 50 percent of all recreational benefits; except for Charles River, which includes willingness to pay for user and non-user values.

g/ Annualized capital costs (assuming 8 1/8 percent interest, 20-year period) plus annual operation and maintenance costs.

h/ Exclud[redacted]ost of Inner Harbor CSO plan except for Constitution Beach portion[redacted]total annual cost of Inner Harbor CSO plan is $16.61 million.

i/ Cost[redacted]tes for Quincy storm sewers are still preliminary. High estima[redacted]quivalent to costs for CSO control in Dorchester Bay.

Table 1-7. Annual Benefits and Costs of Combined Sewer Overflow Controls and Secondary Treatment Control Option (Millions 1982$)

Pollution Control Option		Benefit Estimates by Category: Swimming b/	Recreational Boating	Recreational Fishing	Health d/	Commercial Shell-Fishing e/	Intrinsic f/	Ecological	TOTAL	Total Annual Costs h/
Combined Sewer Overflows and Secondary Treatment										
Constitution Beach	Range:	.98-1.46			.007-.096			Potentially	0.99-1.56	
	Moderate:	1.22			.051			large beneficial	1.27	
Dorchester Bay/ Neponset River	Range:	7.41-11.08			.032-.477			impact on	7.44-11.56	
	Moderate:	9.25			.255			shoreline saltmarshes	9.51	
Quincy Bay	Range:	6.24-9.33			.146-2.15			supporting	6.39-11.48	
	Moderate:	7.78			1.15			fish and invertebrates	8.93	
Hingham Bay	Range:	.215-.322			.003-.039			as well as	.22-.36	
	Moderate:	.269			.021			animals, shorebirds,	.29	
Massachusetts Bay/ Nantasket	Range:	-0-			-0-			and waterfowl.	-0-	
	Moderate:									
Entire Harbor (not including Charles River)	Range:	14.22-22.42 c/	6.46-14.57*	.75-9.49	.198-2.81	.022-.124	10.7-23.2		32.35-72.61*	137.4-
	Moderate:	18.32	10.52	5.12	1.51	.064	17.0		52.53	143.2 h/ i/
Charles River	Range:	-0-	.05-.96	-0-	-0-	-0-	3.14-6.28*		3.19-7.24	10.43
	Moderate:		.51				4.71		5.22	
Four MDC CSO Plans	Range:									
(Constitution, Dorchester, Neponset, Charles River)	Moderate:									

a/ Moderate benefits represent best estimates except for those categories where best estimate is marked by *. Range includes high and low estimate.

b/ Swimming benefits based on conditional logit model. For Quincy town beaches, benefits from increased participation are added since logit model did not include these beaches. All benefits are derived using user day values from logit model.

c/ Includes general recreation benefits at Boston Harbor Islands.

d/ Health benefits for individual areas based on swimming; for entire harbor benefits based on shellfish consumption are also included.

e/ Commercial fishing benefits based on shellfishing; estimates for finfishing and lobstering not available.

f/ Intrinsic benefits based on 50 percent of all recreational benefits; except for Charles River, which includes willingness to pay for user and non-user values.

g/ Annualized capital costs (assuming 8 1/8 percent interest, 20-year period) plus annual operation and maintenance costs.

h/ Excludes cost of Inner Harbor CSO plan except for Constitution Beach portion; total annual cost of Inner Harbor CSO plan is $16.61 million.

i/ Cost estimates for Quincy storm sewers are still preliminary. High estimate is equivalent to costs for CSO control in Dorchester Bay.

annual benefits as estimated and the predicted annual costs. One result that does stand out is that in addition to either secondary treatment or an ocean outfall the CSO problem needs to be addressed if full use restoration and health benefits are to be realized. Some specific conclusions of this study include:

- <u>Monetizable benefits</u>

  -- Swimming benefits and all kinds of recreational benefits are the largest source of the monetizable benefits. In the commercial fishing category, we could only estimate shellfishing benefits. Nonetheless the recreational categories appear to be especially important for urbanized areas such as Boston Harbor where local population density and demand for nearby recreational opportunities are high.

  -- The geographic location of the pollution sources in relation to the receptor or benefit categories is an important factor in determining the type and level of benefits that will be generated by the different treatment options. In the case of Boston Harbor most of the recreation beaches are significantly affected by the CSO discharges and only moderately affected by the STPs. On the other hand, fishing and boating in Harbor waters are more affected by the STP discharges. In the case of fishing and boating, however, a further constraint is marinas and facilities--a constraint on increased participation in these activities not related to pollution control.

  --In our calculations the CSO options can be broken down by MDC Planning Area. For example, benefits related to the Dorchester Bay and Neponset River Plans and the Constitution Beach portion of the Inner Harbor Plan are summarized in Table 1-5. Also, Charles River and Quincy Bay can be isolated. This separation of plans is possible because of the geography of Boston Harbor and it would not be possible, necessarily, for all areas of the country. However, in our case the separation of plans can assist in the determination of the most effective way to allocate CSO control funds.

- <u>Non-monetizable benefits</u>

  -- Several categories include only a partial estimation of benefits. The commercial fishing category includes shellfishing only. Although up to 2.6 million pounds of lobster and 28.4 million pounds of fish are landed annually in the port of Boston, benefits related to this activity were not calculated because of the difficulty of knowing where the fish were caught and how they might be affected by the improved water quality.

-- Intrinsic benefits include aesthetic benefits and benefits such as existence and option value not directly related to use of the water resource. These are best evaluated by willingness-to-pay measures. As can be seen in the case of the Charles River (Table 1-5), they can be quite substantial. For the other areas in this study willingness-to-pay measures were not available, and the intrinsic benefit estimates were related to recreational activity which might not capture all non-user benefits.

-- A potentially large category of benefits not captured in this economic analysis is ecological benefits--benefits related to preservation and restoration of the harbor and bay habitats. The volume of pollutants controlled by the STPs is far greater than that controlled by the CSOs (approximately 30 times greater). Therefore, from an ecological perspective we need to be very concerned about the long term impacts that those heavy metals, toxics and other constituents in the STP effluents have on the harbor and bay habitats even though they are not immediately reflected or easily captured in the economic analysis. The CSOs are also of concern because of their proximity to highly productive saltmarshes along the shoreline.

-- In this study we have looked at uses of the Harbor waters which could be most directly analyzed within our economic analysis framework. This resulted in the exclusion of the Inner Harbor CSO Plan except for the Constitution Beach area. The Inner Harbor CSO control plan (reducing odor, floatables, and toxic substances) would include benefit categories of commercial use, aesthetics and ecological, none of which were monetizable. There are relatively few recreational uses in this area. Given the large amount of effluent discharged (about 11 billion gallons per year), the control costs are quite high and it would not appear that this CSO plan would be as important as the others in its overall impact.

o <u>Costs</u>

-- The costs for the CSO control options are estimates for preferred control alternatives. However, the costs for the Quincy Storm Sewers may not be comparable to the costs as used in the rest of the report. The Quincy cost study is still in the preliminary stages and not nearly as detailed as the other CSO plans. Thus, we show in the summary tables an upper range estimate equal to the CSO control costs for Dorchester Bay, its neighbor to the north.

As is clear from the discussion above, the benefit estimate numbers presented in Tables 1-5 through 1-7 should not be taken as especially important or precise in themselves. They are approximations and represent means computed from ranges, sometimes wide ranges, that have been developed for each benefit category; they are the result of, for the most part, conservative assumptions; and they generally underestimate the benefit values of the treatment options. For instance, as discussed above, ecological benefits have not been included as they are considered non-monetizable (see Section 10). Recreational boating and fishing benefits (except for Charles River) have been computed only for the Harbor as a whole, since data was unavailable to break the totals down by option. The totals were included, however, to give an idea of the possible magnitude of these benefits. Despite these shortcomings, it is apparent from the conclusions that have been drawn that an economic analysis of the beneficial impacts of water quality improvements is feasible and is a useful tool for providing information to decision makers to facilitate improved policy decisions, especially where there is a choice to be made among various alternatives and a limit to the available funding.

1.5 Specific Benefit Estimates

Benefits accrue to households who recreate in, on or near the water, to consumers of commercial fisheries, to consumers who benefit directly and indirectly from the increased economic activity in the primary sector, and to non-users of Harbor waters, who derive intrinsic benefits. Each benefit category, estimation procedure, and benefit estimate are briefly described below.

1.5.1 Recreation

Benefits from increased recreational opportunities are the greatest of all the monetizable benefit categories. Benefits accrue to swimmers, boaters, anglers and those who recreate near the water. Two major components of consumer surplus have been estimated which fully capture benefits from improved water quality: (1) increase in participation, and (2) increase in the price participants are willing to pay per visit for the improved quality of the recreational experience. The following is a brief summary of the three major recreation benefit categories considered in this study.

Swimming. A variety of benefit estimation methodologies were employed to estimate swimming-related benefits. These included: (1) using recreation studies to predict and value increases in participation; (2) applying a travel cost, conditional logit model to estimates gains in consumer surplus due to increased participation and increased satisfaction per trip; and (3) calculating consumer losses stemming from beach closings. Results from the travel cost model are the most accurate of all the methodologies because of the theoretical and empirical strengths of the logit model. Benefits associated with the CSO control options are substantial: $18-19 million for swimmers throughout the Harbor area for a full plan of STP and CSO controls. About $15 million of this is related to CSO controls because of the proximity of their discharges to the shoreline beaches. (See Chapter 6.)

Fishing and Boating. Fishing and boating benefits have been calculated only for the entire Harbor study area because of data limitations. Benefits for both these categories are substantial: $12 to 15 million for both activities for combined STP and CSO controls. (See Chapter 6.)

Boston Harbor Islands--All Recreation Activities. The Boston Harbor Islands are a unique recreation resource that will benefit from improved water quality resulting from the implementation of the STP treatment alternatives.

Recreational data was used to predict increase in participation in all Boston Harbor Island activities. Benefits total $1 to 3 million. (See Chapter 6.)

1.5.2 Health

Health benefits from water pollution abatement include willingness to pay to avoid swimming-related illnesses and shellfish consumption-related illnesses. Dose-response data were used to evaluate swimming-illness benefits. No such functions exist for consumption of shellfish, and thus these benefits were developed by assuming that a percentage reduction in shellfish-borne diseases is directly proportional to percentage reduction in the concentration of the fecal coliform in the water. Total health benefits from CSO and STP controls are about $1.5 million. They are lowest at Constitution Beach and highest at the Wollaston/Quincy beaches, which have the highest swimming attendance and are in close proximity to the Quincy storm sewers. Shellfish consumption benefits can only be linked to pollution reduction throughout the entire harbor. Benefits are small, from $0.001 million to $0.005 million. (See Chapter 7.)

1.5.3 Commercial Fisheries

Water pollution abatement in Boston Harbor would probably result in a reclassification of shellfish beds from grossly contaminated (closed beds) to moderately contaminated (restricted beds), thereby allowing increased shellfish harvesting with depuration. Moderate benefits are about $0.06 million for combined STP and CSO controls. (See Chapter 8.) These benefits do not include the sizable commercial catches of finfish and lobster. Current annual value of these catches reaches $18 million. We were not able to calculate incremental annual benefits for this portion of commercial fishing benefits, however.

1.5.4 Intrinsic Benefits

Water pollution abatement is predicted to have an important effect on benefits which are not specifically related to actual water use, such as option, existence, and aesthetic values. Except for the Charles River, because of the lack of appropriate willingness to pay survey data which could be applied to the different treatment alternatives in the study area, intrinsic values have been estimated by assuming that non-user benefits are one-half as great as recreational user benefits. (See Chapter 9.) Moderate estimates for intrinsic benefits total $16-17 million.

1.5.5 Ecological Impacts

Pollution abatement might positively influence ecological processes in saltmarsh areas throughout the harbor. Although attempts have been made to estimate the economic value of marshlands by valuing the role of the marsh as a factor of production, and by estimating the cost of duplicating these functions, it was not possible to apply these results to the Boston Harbor study area. This is because the connection between the levels of pollution control, the subseq ›nt reduction of pollutant loadings to the water column and the functioning of the marshlands is unknown for the harbor. Furthermore, the role of pollutants already in the sediments, that could be resuspended into the water as loadings are reduced, is not well understood at this time. Therefore, these benefits have been considered non-monetizeable. (See Chapter 10.)

The adverse ecological impacts believed to be caused by current and past levels of pollutant loadings include:

-- the alteration of benthic populations which may reduce the food supply, thereby resulting in a decrease in commercially valuable fish variety and numbers;

-- the accumulation of toxics by benthic fauna and then passage up the food chain where they pose a health risk to consumers (copper, mercury, PCBs, silver found in tissues of lobster and winter flounder);

-- bioaccumulation which can affect species reproduction, increase potential for disease (fin erosion in winter flounder associated with PCB contamination), and impair predator avoidance behavior which could result in reduced numbers and variety of fish.

Important commercial species that may be adversely impacted include lobsters, manhaden, cod, bluefish, striped bass and eels. Ecological benefits would accrue to the pollution control measures if the reduction in pollutant loadings caused reductions in the aforementioned adverse impacts.

The ecological benefits of the STP options may be larger because the volume of discharge is about 30 times as great as for the CSOs. However, the ocean outfall option will negatively impact some of the areas in Massachusetts Bay which include:

-- commercially valuable species such as tautog, cod, pollack, haddock, halibut, mackeral; and

-- migratory and endangered species such as whales, sea turtles, sturgeon and the Peregrine falcon.

1.5.6 Secondary Effects

Improving water quality will result in secondary effects from increases in economic activity generated in an area by direct impacts, such as commercial fisheries or recreation activities. A range of input and output multipliers were applied to each benefit category to compute all secondary economic effects. Secondary effects cannot be linked to each pollution control option for every primary benefit category because some of the benefit categories, such as fishing and boating, could only be developed on a harbor-wide basis. We have chosen to refer to these values as effects, rather than benefits, because only under certain circumstances can secondary effects be considered benefits and the labor market analysis required for delineation and definition of these circumstances was beyond the scope of this case study. For these reasons we have calculated the different secondary effects, but have not included the dollar value in the summary of total pollution control benefits. (See Chapter 11.)

1.5.7 Charles River Basin

Benefits to instream, near-stream users and non-users of the Charles River were calculated by estimating increase in boating participation and by applying results from a willingness to pay survey. Boating benefits are small ($0.51 million) because all river acres in the Charles River Basin currently are used for boating and because user day values used to value this increase are moderate. The benefits of improving water quality along the Charles more accurately are measured by applying results of a willingness to pay survey, which captures benefits to users and non-users alike. Benefits calculated using this methodology are substantial: $4.7 million. Despite the large size of these benefits, they are approximately half of the estimated $10.43 million annual cost of implementing the Charles River Basin CSO plan. (See Chapter 12.)

1.6 Guide to the Report

This chapter has summarized the features of the study area, the treatment alternatives and the benefit categories. It also has presented a brief analysis of the treatment options and a brief summary of study results and conclusions. The specific STP and CSO treatment options are discussed in detail in Sections 2 and 3. Their effects on Harbor water quality are included in Section 4. Section 5 presents a brief introduction to the theoretical and methodological approaches used to measure benefits from improving water quality, and discusses the benefit categories applicable to this case study. The next six sections describe each benefit category and include benefit estimation methodology, data bases used in the analysis, benefit estimates, and limits to the analyses: Section 6, Recreation Benefits; Section 7, Health Benefits; Section 8, Commercial Fisheries; Section 9, Intrinsic Benefits; Section 10, Ecological Benefits; and Section 11, Secondary Effects. Section 12 presents a separate analysis of benefits from implementing the Charles River Basin CSO Plan.

Several Appendices follow the major text. Appendix A gives a more detailed view of STP treatment alternatives and their effects on Harbor water quality. Appendix B presents detailed calculations for the different methodologies used to estimate recreation benefits and includes a description of the major recreation sources used in this analysis. Appendix C explains how health benefits are calculated and Appendix D presents a step by step analysis of commercial fisheries benefits calculations. Appendix E summarizes calculations of recreation boating benefits from water quality improvement in the Charles River Basin.

Section 2

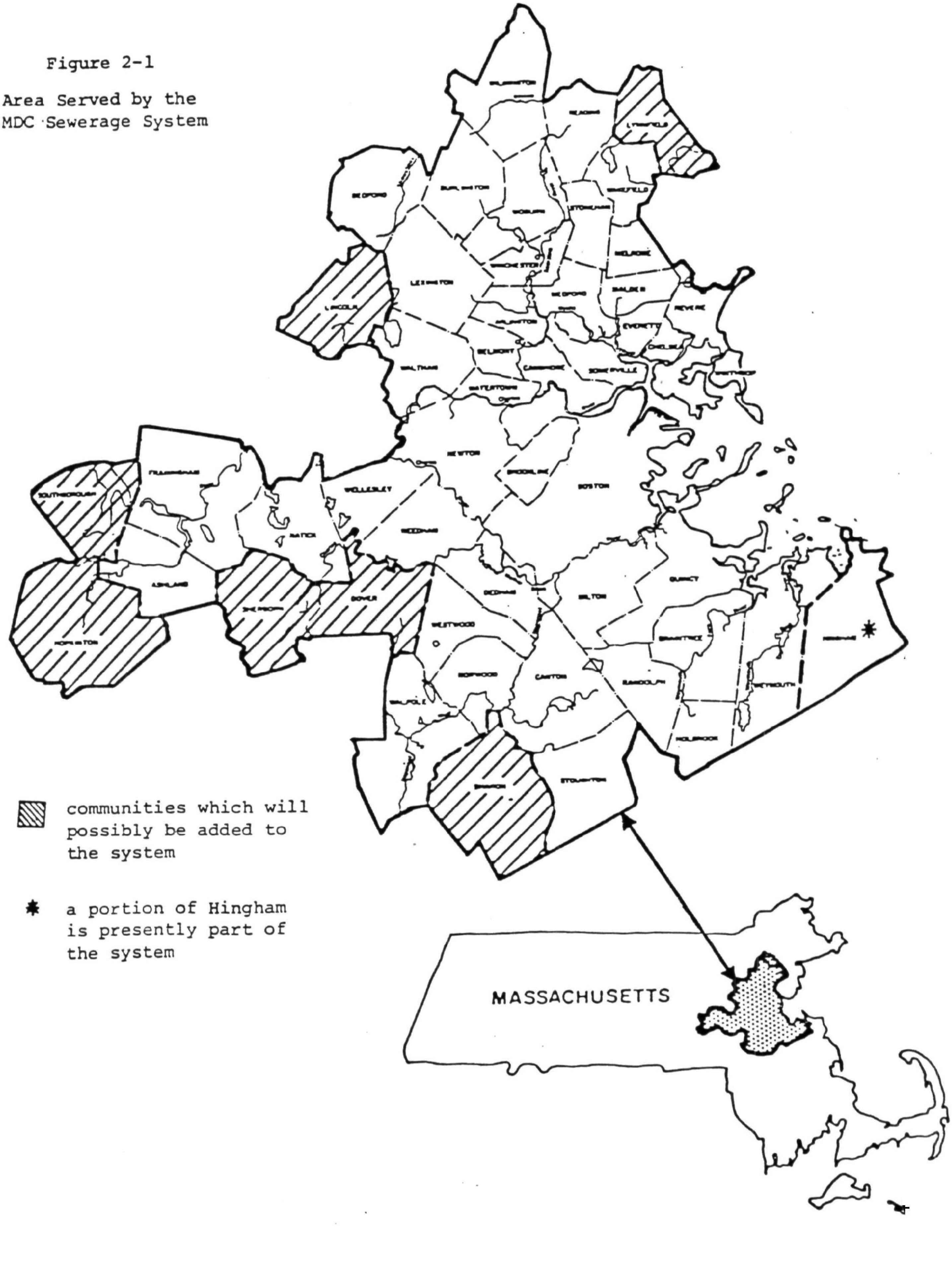
Municipal Sewage Treatment Plant Operations, Options and Water Quality Impacts

The 43 towns and cities belonging to the Metropolitan Sewage System (see Figure 2-1) generated approximately 167,900 million gallons of raw, mixed domestic, commercial, and industrial wastewater in 1980. Among the responsibilities of the Metropolitan District Commission (MDC), a public service authority for the 43 municipalities, is the collection, treatment and disposal of these municipal wastes. To fulfill its responsibility, the MDC owns and operates two sewage treatment plants (STP), one at Deer Island and the other at Nut Island, which handle the wastes from the northern and southern member municipalities, respectively. At present, both plants are designed to carry out primary treatment, which is essentially a screening, sedimentation, and chlorination procedure. They then discharge both the treated effluent and concentrated, digested sludges into the outer harbor.

Under the legal mandate of the 1972 and 1977 Clean Water Act and Amendments, the Environmental Protection Agency (EPA) established standards and procedures for the treatment and disposal of municipal wastes. The new regulations call for treatment at the secondary level (in addition to primary treatment) and a cessation of sludge disposal in the ocean. The intent of the regulation is to reduce the degradation of water quality that is caused by municipal waste loadings.

Figure 2-1

Area Served by the MDC Sewerage System



▧ communities which will possibly be added to the system

✱ a portion of Hingham is presently part of the system

Prompted by the aforementioned regulation, numerous studies have been undertaken to determine the engineering feasibility of treatment alternatives, how to manage and handle residual sludges, etc. For the most part, these studies have limited their analyses to what can be done to satisfy the new regulatory requirements, either through direct compliance (secondary treatment and no sludge discharges to the ocean) or with options available through waiver opportunities (upgraded primary treatment with a deep ocean outfall, sludge barging).

Section 3 discusses the technical, environmental, and financial options for combined sewers in the Boston Metropolitan area. STPs are discussed here separately. At times it will be necessary to bring combined sewers into the following discussion since their performance can affect that of the STPs and vice-versa.

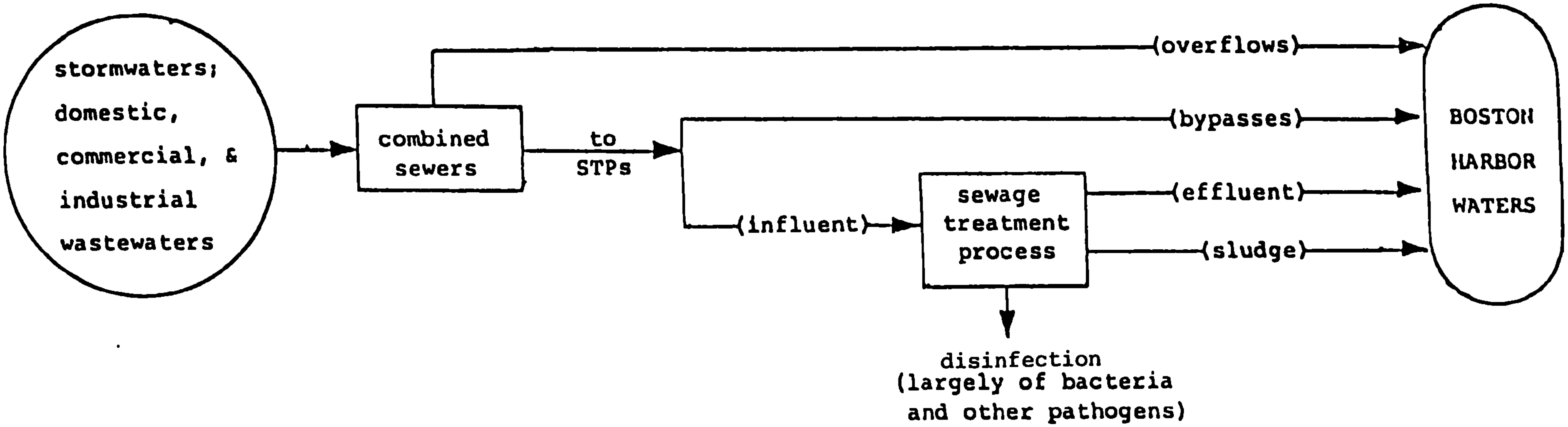
The intent of this section is to: (1) describe current Deer and Nut Island STP performance and pollutant loadings; (2) present the financial and expected performance characteristics of two proposed STP options; and (3) discuss the potential water quality impacts of these proposed STP options. A vast amount of information was analyzed for the development of this chapter. What is presented here is essentially the conclusions of that effort. The background and formulation of the most important analyses are explained in Appendix A.1.

2.1 Current STP Performance

The existing Deer Island and Nut Island STPs are designed to treat municipal wastewaters at the primary level. As the flow diagram of Figure 2-2 illustrates, most constituents of the municipalities' wastewaters eventually

Figure 2-2.

Schematic of Sources of Pollutant Loadings to Boston Harbor



reach the harbor in one form or another, with the exception of a portion of the organic constituents which are lost through disinfection in the treatment process. Metals and other non-destructables remain relatively unchanged while passing through the treatment system and are, therefore, discharged in either the sludges or effluent from the STPs.[a] The STP-source loadings have been calculated on an annual basis for comparison of their relative magnitudes; they are presented in Table 2-1. Effluent and sludge loading information was calculated using measurements taken of wastewaters that had undergone complete treatment, which does not account for raw (untreated) wastewater discharges. Therefore, loadings from STP bypasses of raw wastewaters were calculated from influent composition and bypass volume data.[b]

Both the treated wastewaters and the solids sludges extracted by STP treatment are discharged through local outfalls into Presidents and close to Nantasket Roads from the Deer Island and Nut Island STPs, respectively. These two "Roads" are the major deep and fast-flowing channels of the Harbor (see Figure 2-3 for their location). Whereas much of the harbor is only 10 to 15 feet deep, the depths of President and Nantasket Roads range up to 90 feet. The STPs discharge to these locations because of their capacity for carrying and dispersing effluent and sludge loads. The plants' effluents are di' 'harged continuously whereas sludges ideally are released only on outgoing tides. Since the sludges generally contain a high percentage of the original influent's pollutants, their releases are timed for maximum removal from the

---

[a] Some chemical recombination and physical change of the wastewater constituents can be expected, but essentially, mass is conserved.

[b] CSO loadings have not been calculated from this same raw wastewater information because data regarding the frequency, duration, stormwater dilution, and volumes of overflow events are not available.

Table 2-1.

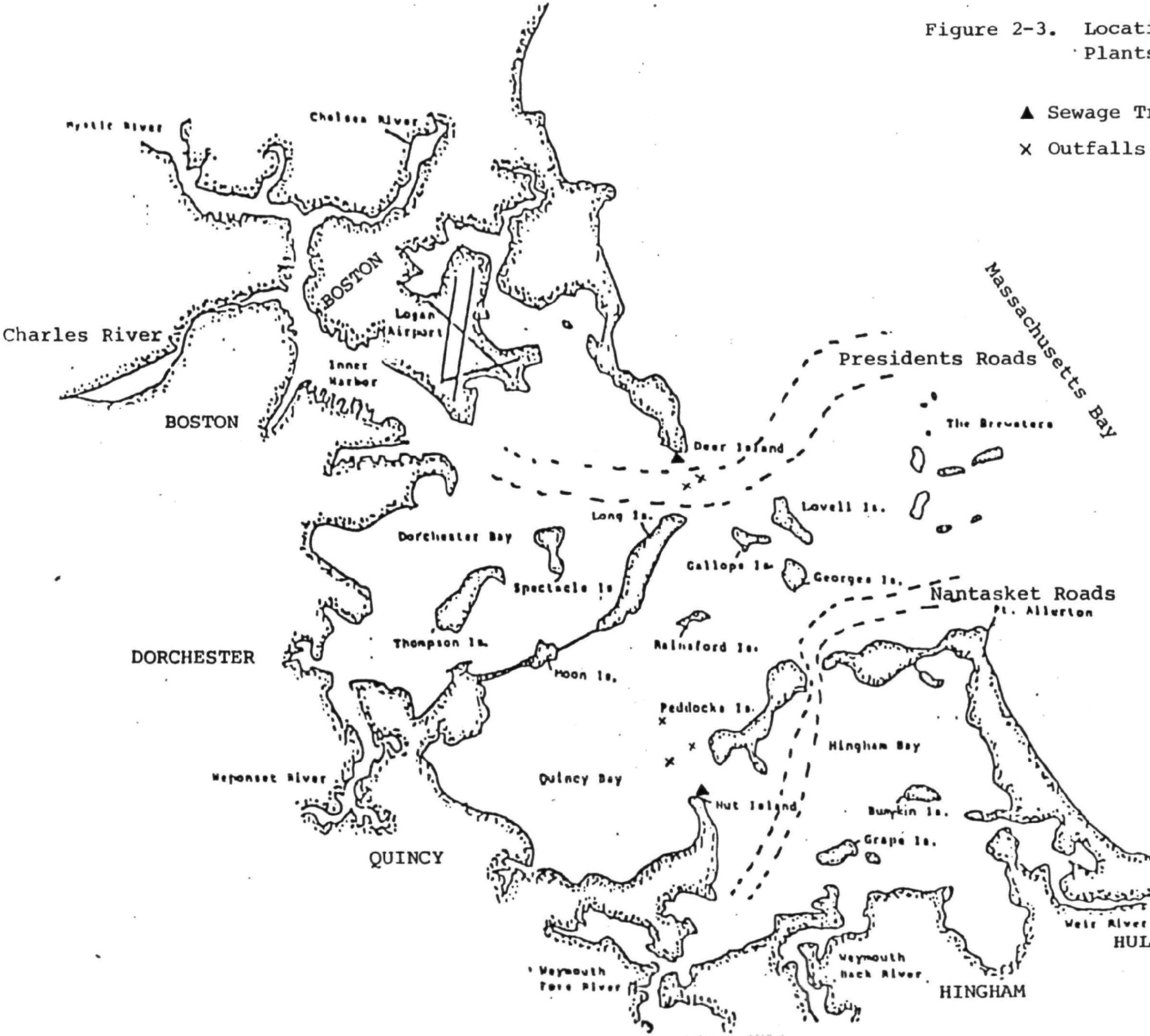
Comparison of STP Loadings for Deer and Nut Islands Combined [a]

	Existing Loadings				STP Effluent from Ocean Outfall (lbs/yr)	STP Effluent from Secondary Treatment (lbs/yr)
	STP Effluent (lbs/yr)	STP Sludges (lbs/yr)	STP Bypasses (lbs/yr)	Total STP Discharges (lbs/yr)		
BOD_5	154×10^6	17×10^6	$10\text{-}15 \times 10^6$	$181\text{-}186 \times 10^6$	180×10^6	46×10^6
TSS	124×10^6	45×10^6	$10\text{-}15 \times 10^6$	$179\text{-}184 \times 10^6$	135×10^6	46×10^6
Cd	26,000	4,800	1,000	31,800	26,000	23,000
Cr	138,000	72,600	4,700	215,300	138,000	101,000
Cu	325,000	115,700	22,400	463,100	325,000	159,000
Pb	178,000	36,500	6,300	220,800	178,000	141,000
Hg	2,000	700	100	2,800	2,000	0
Ni	241,000	25,900	22,700	289,600	241,000	172,000
Zn	702,000	222,700	29,000	953,700	702,000	419,000

[a] Conversions of mg/l data to lbs/year figures made assuming 500 million gal/day of effluent discharged from Deer Island and Nut Island combined. See Appendix A.1 for further explanation of calculations.

Sources: US EPA (1978), Tables 3.2-6 and 3.2-7; US EPA (1983), p.2; Metcalf & Eddy (1982), Tables 3-10 and 3-11; ERT (1978), Table 2.2-8; Dumanoski (1982).

Figure 2-3. Location of Sewage Treatment Plants in Boston Harbor Study Area



Harbor. However, due to outfall pipe deterioration, inadequate holding capacity, and system malfunctions, the sludge releases are not always properly co-ordinated with the tides. Hydroscience's model of sludge transport from the outfalls predicts that 20 percent of the sludges discharged on the outgoing tide are carried back into the Harbor on the return tide.

The Deer and Nut Island STPs are currently operating below design criteria. This has led to:

a. the bypassing of raw sewage directly into the Harbor;

b. the release of sludges on currents other than the out-going tide;

c. the backing up of sewers from the STP, causing the combined sewers to overflow; backups can occur if some unit of the STP malfunctions, halting incoming flows or if incoming flows simply exceed the capacity of the system;

d. overall, less than design-optimal treatment performance because of tanks settling, tank covers missing, screens in poor condition, pumps malfunctioning, and other operational problems, including the problem of saltwater influent into STP due to malfunctioning tide gates.

A properly operating and properly sized sewage treatment system could alleviate these problems. Necessary steps to correct the above deficiencies include:

a. improving the capacity of the combined sewers (particularly holding facilities) in order to moderate heavy (storm) flows to the STPs; repairing STPs to restore capacity (pumping, etc.); expanding STPs to increase capacity (of holding tanks, etc.);

b. that sludges be released only on out-going tides (sludge-release timing problems) or that another method of sludge disposal be found;

c. that either or both of the following actions be taken to solve the influent back-up problem:

   o expand combined sewer facilities to accommodate what the STP cannot, and/or

   o increase STP ability to accept incoming flows;

d. the repair of units to restore their design functions and performance.

Funds recently have become available for the repair and rehabilitation of Nut and Deer Islands' STPs, which may restore their original design performance. Increased operation and maintenance efforts made by the MDC can result in a change in the Harbor's water quality prior to implementation of any of the proposed STP options. Actual loadings to the Harbor might be more consistent with the sum of the first two columns of Table 2-1 once the STPs are operating well, whereas now the loads are higher since bypassing occurs.

2.2 STP Options and Costs

There are many options under consideration for STP modification. They represent different combinations of primary and secondary level treatment facilities at Deer, Nut and/or Long Islands, with either local or deep ocean outfalls. Two options have been chosen for the purposes of this analysis: (1) upgraded primary treatment with a deep ocean outfall and (2) secondary treatment with a Presidents Roads (local) outfall. Because of resource limitations, only two options could be included.

At the time of this analysis several other options are under discussion [a], but all are either primary treatment with a deep ocean outfall or some type of secondary treatment. Thus, the options described here are meant to be representative of the range of options possible under current federal regulations.

One of the STP options considered here calls for upgrading the existing facilities to achieve primary treatment plus the construction of a deep ocean outfall diffuser system to discharge the combined, treated effluents from Deer and Nut Island plants into the waters of Massachusetts Bay, out of the Inner Harbor estuary, at a depth of 32 M (105 feet) (see Figure 2-3). The outfall system would consist of a 10 foot diameter pipeline extending 4.7 miles from Nut Island; 56.6 cubic meters per second (1.29 billion gallons per day) capacity effluent pumping station on Deer Island; and an outfall tunnel 7.5 miles long and 19 feet in diameter, terminating at a diffuser manifold 1.3 miles in length. The proposed deep ocean outfall would discharge the treated effluents from the Deer Island and Nut Island facilities. At the mouth of the outfall would be a diffuser, which is designed to rest on the ocean floor at a depth of approximately 100 feet.

The other STP option includes expanded primary treatment at the Nut Island facility with the waste flow sent to Deer Island where all of the system's wastes would be treated at the secondary level. The combined local outfall would be into President's Roads (see Figure 2-3).

---

[a] See CE Maguire (1983). Specific options were chosen in consultation with Region I, Environmental Protection Agency, personnel. At the time of this analysis these were the options preferred by the MDC.

The capital and operating and maintenance costs for the two STP options are presented in Table 2-2, and the expected loadings in terms of pollutant concentrations are compared to concentrations in the existing STP effluents in Table 2-3. These options and their associated costs assume that the present facilities operated by the MDC will be modified according to the presently planned "fast-track improvements". The costs of these immediate upgrade improvements will be $10 million at Nut Island and $40 million at Deer Island (CE Maguire, 1983).

2.3 Areas Impacted by STP Discharges

Existing water quality in different areas in the Harbor is due to current STP effluent discharges, bypasses and sludge discharges as well as the natural composition of the waters, CSOs, surface runoff, long-term discharges to the harbor (industrial, residential STPs, etc.), discharges from marine craft, etc.

In terms of the incremental contributions to pollutant concentrations made by STPs, some areas are impacted more than others. The affected areas may be grouped as follows (see Figure 2-4):

- areas of heaviest loadings;
  - between Deer Island and Long Island
  - between Long Island and Lovell Island
  - Quincy Bay, south of Moon Island
  - between Nut and Peddocks Island
- areas of moderate loadings:
  - east of Lovell Island
  - western half of Hingham Bay
  - northwest and northeast of Deer Island STP
  - Quincy Bay shoreline

Table 2-2. Costs of the Two STP Options

(Millions 1982$)

Wastewater Treatment STP Options	Capital Cost (1983$)	Capital Cost (1982$)[a/]	Annualized Costs Capital[b/]	Annualized Costs O&M	Total
Upgraded Primary With Ocean Outfall	774.8	728.9	74.9	22.0	96.9
Secondary	887.4	834.8	85.8	45.2	131.0

a/ Expressed in 1982$ (ENR=3825) because benefit estimates are expressed in 1982$ (CPI-U=289.4)

b/ Based on 8 1/8 percent interest and 20 year period.

Source: CE Maguire (Draft, 1983), Table 2. These costs are to be considered preliminary estimates only.

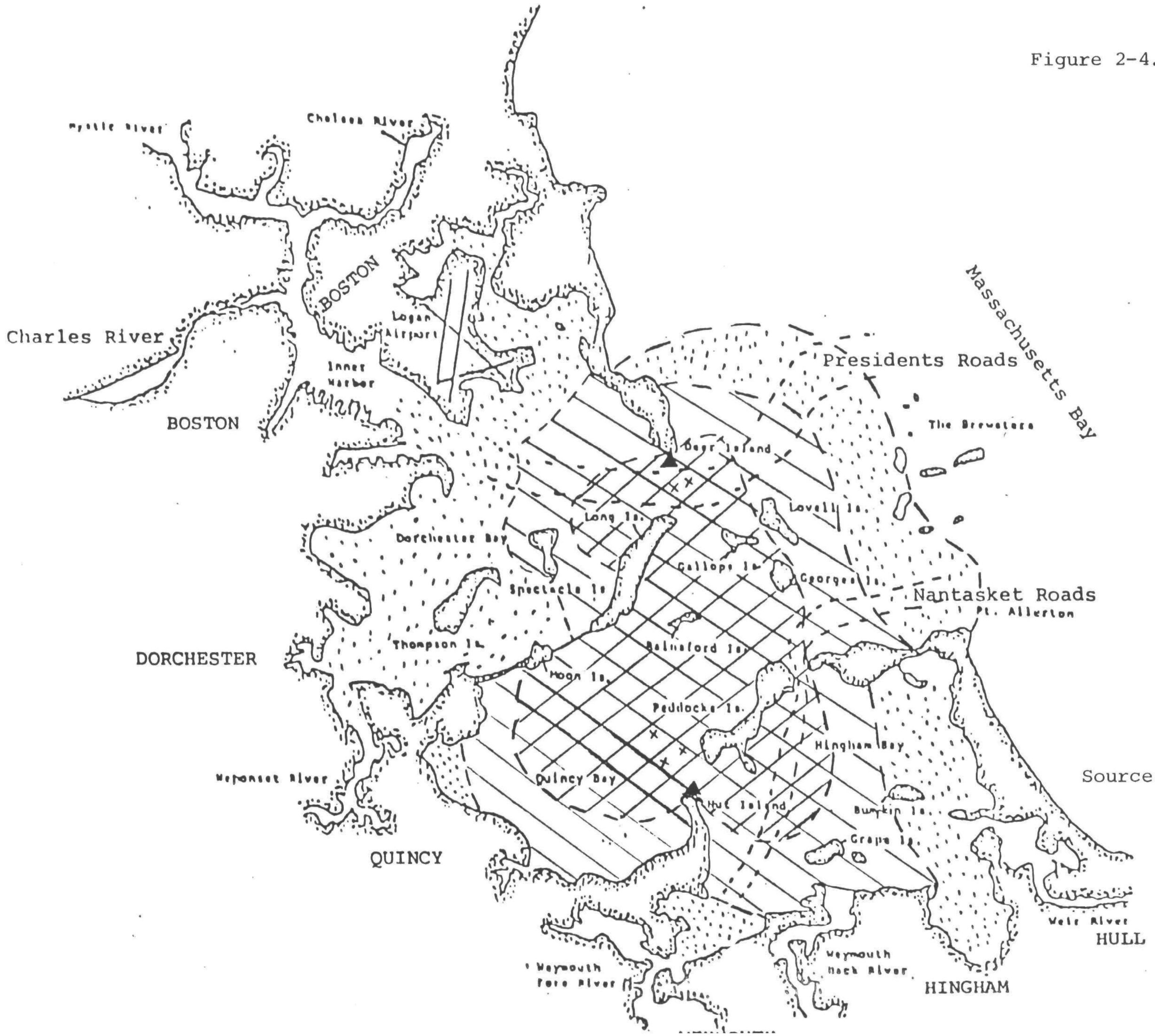
Table 2-3. Pollutant Concentrations in Effluent for STP Options

Effluent Pollutants		Existing STP	Ocean Outfall Option	Secondary Option
BOD_5	mg/l	107	115	30
	% removal	29	28	81
TSS	mg/l	87	86	30
	% removal	55	47	81
Cadmium	mg/l	.017	.017	.015
	% removal	15	15	25
Chromium	mg/l	.090	.090	.066
	% removal	16	16	38
Copper	mg/l	.212	.212	.104
	% removal	39	39	70
Lead	mg/l	.116	.116	.094
	% removal	19	19	34
Mercury	mg/l	.0011	.0011	.001
	% removal	21	21	28
Nickel	mg/l	.157	.157	.112
	% removal	72	72	80
Zinc	mg/l	.458	.458	.273
	% removal	33	33	60

Sources: US EPA (1978), Tables 3.2-6 and 3.2-7; US EPA (1983), p.2; Metcalf & Eddy (1982), Tables 3-10 and 3-11.

Note: Existing values for the metals are averages of sampling done in years 1975-1977. Samples taken in 1982 show decreases in chromium, lead, and zinc with increases in the other metals (Metcalf & Eddy, 1983). Whether this represents a significant decreasing trend can only be ascertained through a concerted monitoring plan.

Figure 2-4. Dispersion of Current STP Discharges



Dilution Ratio (Seawater:Effluent)

≤50:1

≤100:1

≤200:1

>200 to 1000:1

▲ Sewage Treatment Plants

x Outfalls

Source: Metcalf & Eddy (1979), Figure 6-16.

- o areas minimally influenced by STP discharges:
  - the Brewsters Islands
  - eastern half of Hingham Bay
  - Inner harbor
  - Dorchester Bay shoreline
  - Neponset River

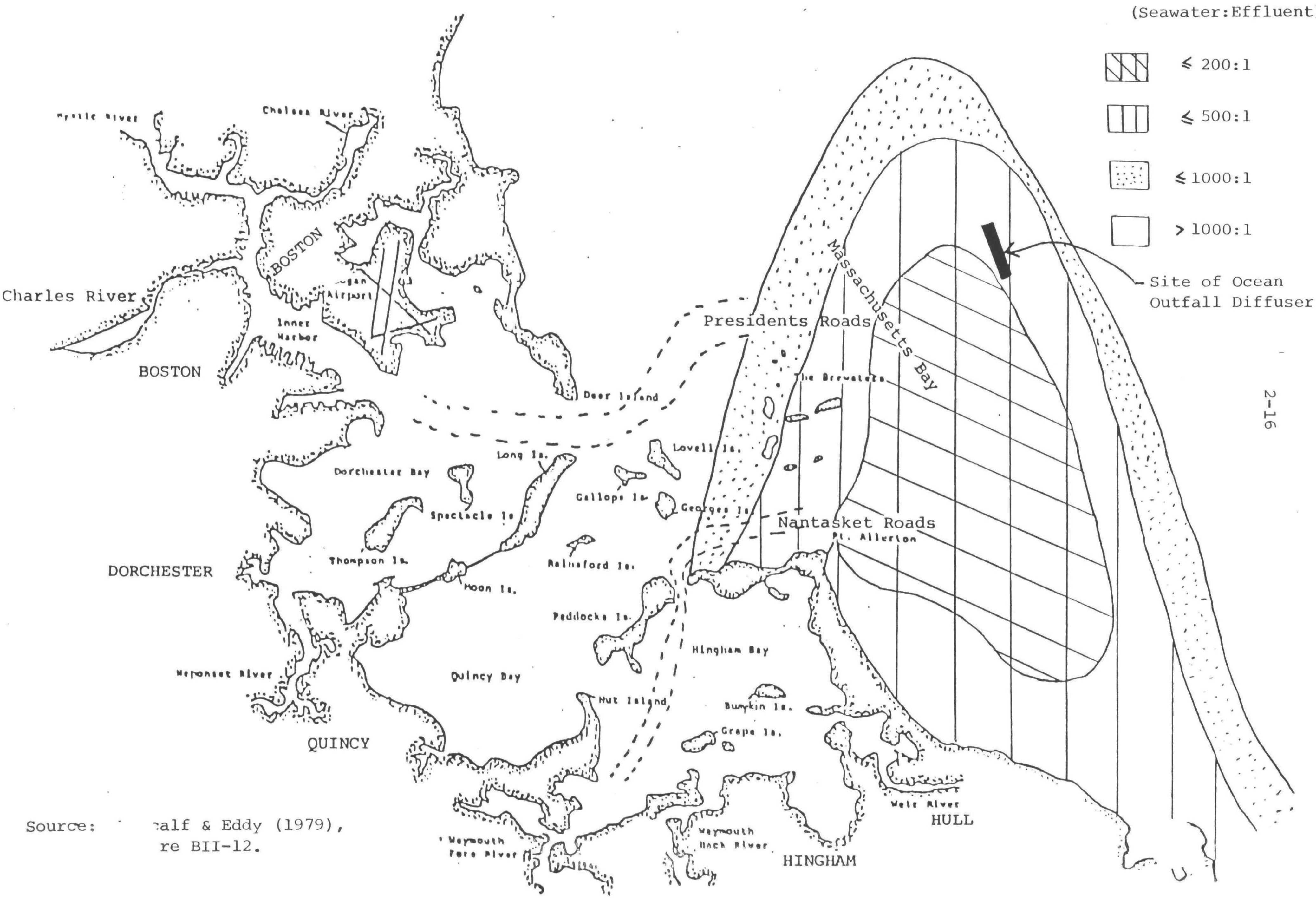
The highest pollution loads are located along the incoming and outgoing tidal paths of Presidents and Nantasket Roads (the two main current channels of the harbor, in which Deer Island and Nut Island STPs have their outfalls, respectively). Current STP discharges have a greater impact on the Outer Harbor Islands and the eastern part of Quincy Bay than on the other shoreline at the perimeter of the harbor.

If a deep ocean outfall option is selected, the harbor will certainly experience a reduction in pollutant loadings. The reduction for the harbor creates a trade-off, however, by introducing wastes to previously unpolluted areas. Figure 2-5 identifies three zones of impact for the proposed ocean outfall option. In terms of the areas of concern to this benefits study, the zones which sustain degradation of water quality due to the construction of the deep ocean outfall are:

- o Massachusetts Bay (highest level of impact); and
- o Nantasket Beach and the Brewsters (moderate level of impact).

The advantage of the proposed deep ocean outfall is the dilution of effluent that is obtainable in its vicinity as compared to the dilution in the vicinity of the local outfalls currently in use in the harbor. The disadvantage is that total pollutant loadings are not reduced to the extent they would be under the secondary treatment option, and the proposed location may not provide for sufficient transport and dispersion of the diluted wastewater.

Figure 2-5. Dispersion of Proposed Ocean Outfall Discharges

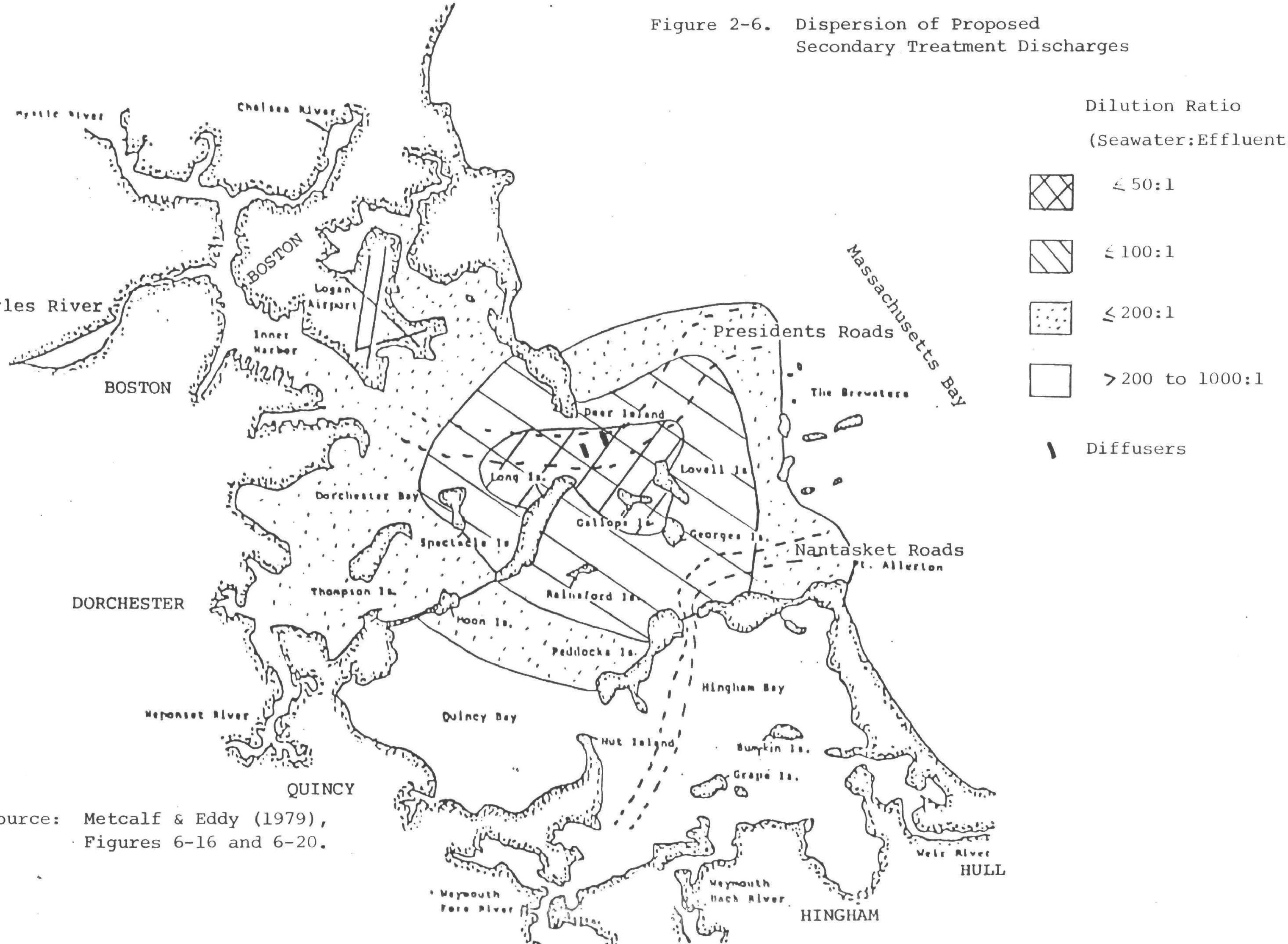


Source: calf & Eddy (1979), re BII-12.

The secondary treatment option considered in this study will reduce total pollutant loadings and change the location of the current STP discharges in Nantasket and Presidents Roads to a single discharge within the harbor in Presidents Roads. Figure 2-6 identifies the areas in the harbor which will be affected by this discharge. The highest level of impact will be on the Outer Harbor Islands.

None of the proposed STP options will eliminate the pollution of harbor waters. The incremental loadings to the harbor waters can be reduced, thereby improving water quality. Most pollutants (i.e., metals and solids) tend to settle out of the water column and into the sediments. Therefore, the pollutant concentrations of Boston Harbor sediments will probably continue to rise unless the rate of pollutant loading can be supressed by some sort of biological, chemical, or physical neutralization process within the sediments. What happens to pollutants in sediments is not known, however, nor are the effects on aquatic organisms of pollutant build-up in sediments fully understood. The present and potential status of water and sediment qualities can be quantified but the significance of such qualities is not clear.

Figure 2-6. Dispersion of Proposed Secondary Treatment Discharges



Source: Metcalf & Eddy (1979), Figures 6-16 and 6-20.

References

Dumanoski, Diane, 1982, Boston Globe, December 19, 20, and 21, Boston, MA.

Environmental Research and Technology, 1978, Draft Report for the National Science Foundation, C-PRA77-15337.

Metcalf & Eddy, Inc., June, 1982, Nut Island Wastewater Treatment Plant Facilities Planning Project, Phase I, Site Options Study, for the Metropolitan District Commission, Boston, MA.

Metcalf & Eddy Inc., September 13, 1979, Application for Modification of Secondary Treatment Requirements for Its Deer Island and Nut Island Effluent Discharges into Marine Waters, for the Metropolitan District Commission, Boston, MA.

Metcalf & Eddy, Inc., January 1983, Application for Modification of Secondary Treatment Requirements for Its Deer Island and Nut Island Effluent Discharges into Marine Waters, Executive Summary, for the Metropolitan District Commission, Boston, MA.

Maguire, CE, Inc., December 20, 1983, Preliminary Screening Results for Boston Harbor DEIS Supplemental, for Environmental Protection Agency, Region I, Boston, MA.

U.S. Environmental Protection Agency, June 30, 1983, Analysis of the Section 301(h) Secondary Treatment Waiver Application for Boston Metropolitan District Commission, Office of Marine Discharge Evaluation, Washington, DC.

U.S. Environmental Protection Agency, August 1978, Draft Environmental Impact Statement on the Upgrading of the Boston Metropolitan Area Sewerage System. Boston, MA.

Section 3

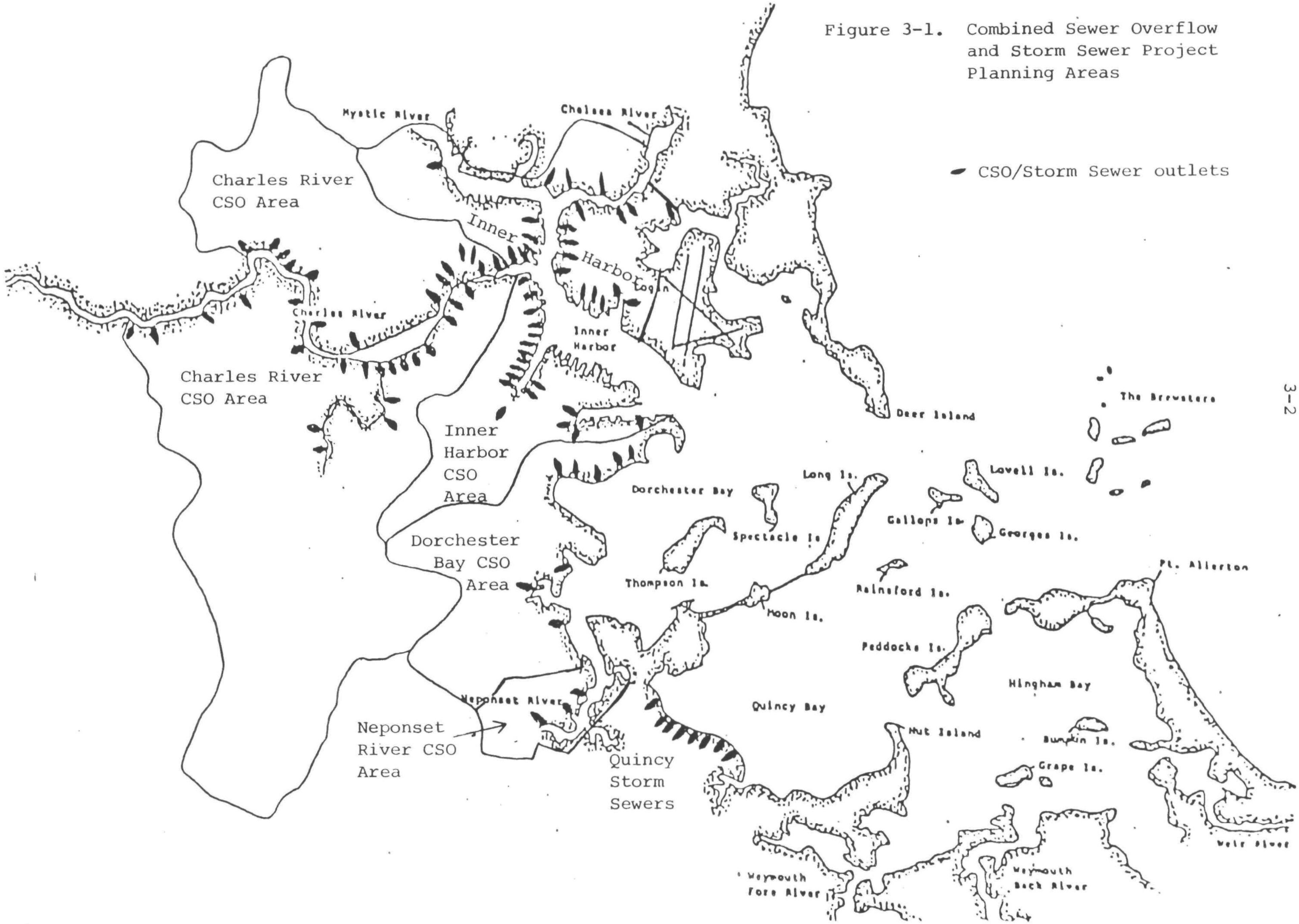
Combined Sewer Overflow Control in Boston Harbor

In its effort to develop a comprehensive plan for combined sewer overflow (CSO) control in Boston Harbor, the Metropolitan District Commission (MDC) has designated four CSO planning areas. The four areas are defined on the basis of their existing water use and coastal use patterns. The designated areas are: (1) Dorchester Bay, (2) Neponset River, (3) Inner Harbor and (4) Charles River Basin (see Figure 3-1). In addition, the City of Quincy has storm sewer outfalls into Quincy Bay which may impact the study area in a manner similar to the CSOs. For each of these five planning areas engineering firms have been hired to study alternative methods of control. All information pertaining to specific areas is drawn from the contractor reports, and these reports are referenced at the end of this Section.

3.1 Scope of the Combined Sewer Overflow Problem

The water quality of all four planning areas is compromised by pollution from combined sewer overflows, stormwater discharges, and dry weather overflows (DWO) (see Figure 3-1). Storm-related combined sewer overflows vary in duration (depending on the nature of the storm) and occur from 50 to 100 times a year (depending on the planning area location). Dry weather overflows may be caused by sewer blockages, regulator malfunctions and/or tide gate failures. DWO's are continual discharges of sanitary

Figure 3-1. Combined Sewer Overflow and Storm Sewer Project Planning Areas



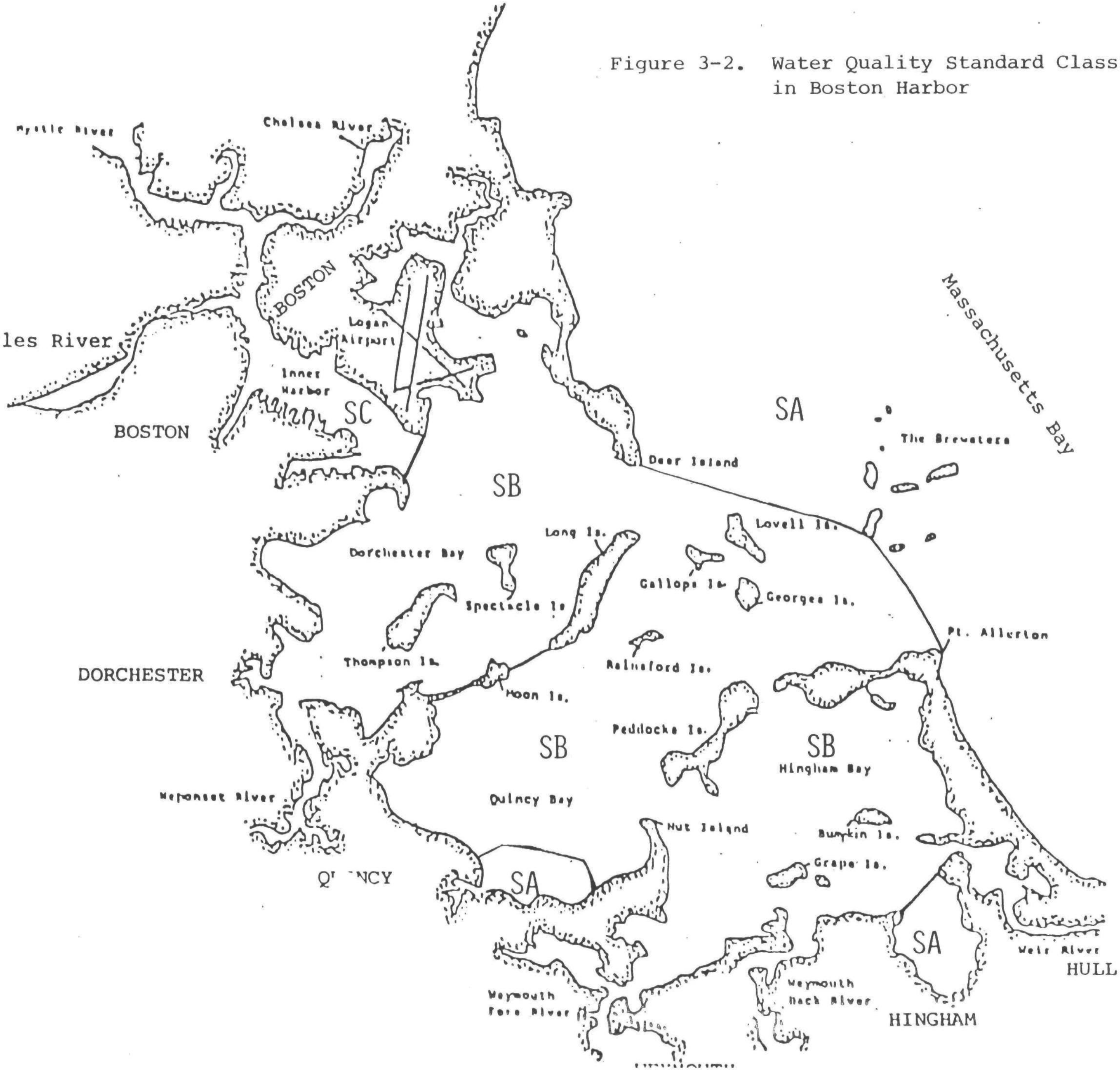
wastewater and are considered by the MDC to be the single most important source of pollution in Boston Harbor. Treatment of dry weather overflows is considered in all the CSO plans.

Different parts of Boston Harbor have different standards (see Figure 3-2). The Dorchester Bay and Neponset River Estuary areas are both classified as SB. An SB classification implies suitability for primary water contact sports (i.e., swimming) and shellfishing and means that the dissolved oxygen in the water must be greater than 6.0 mg/l and the total coliform count must have a median level less than 700 MPN/100 ml. The Inner Harbor is classified as SC which makes it suitable for secondary recreation and means that dissolved oxygen must be greater than 6.0 mg/l and the total coliform count must have a median not greater than 1000 MPN/100 ml. The Charles River is classified as "C", the fresh water counterpart of SC, which makes the river suitable for secondary recreation.

Some areas of Quincy Bay and Hingham Bay, outside the CSO planning areas but within this studies' boundaries, are classified SA. An SA classification is the same as SB for DO but has stricter limits on total coliform counts (70 MPN/100ml) for the protection and propagation of aquatic life and so that shellfish harvesting can take place without depuration in approved areas (Metcalf & Eddy, 1979). The plan for the city of Quincy's storm sewers is discussed separately below (Section 3.6).

The MDC and its contractors found the following violations of the standards, of which all of the violations are caused jointly by combined sewer and dry weather overflows (MDC, April 1982) and by STP loadings:

Figure 3-2. Water Quality Standard Classifications in Boston Harbor



- o Coliform bacteria standards are intermittently or continually violated in all areas.

- o Dissolved oxygen standards are frequently violated in the Charles River Basin planning area and in the Inner Harbor; they are less frequently violated in Dorchester Bay and the Neponset River Estuary and Constitution Beach.

- o Suspended solids possibly limit the most sensitive designated uses of receiving waters; settleable solids cause violations in certain locations, and floating materials, oil and grease violate the standards in all areas. The standards for all of these parameters are non-quantitative.

- o Nutrients are creating enriched conditions conducive to excessive algal growth in fresh waters in the Neponset River Estuary.

- o Heavy metals are potentially significant contaminants to finfish and shellfish in all areas.

- o The shellfishing standards for total coliforms are violated in the Neponset River Estuary, in much of Dorchester Bay, and in areas north and east of Logan International Airport.

In order to deal with these violations, the MDC concluded that its efforts to upgrade water quality should meet the following objectives (MDC, April 1982):

a. eliminate dry weather overflows;

b. reduce the frequency and volume of untreated CSO's

c. reduce the release of pathogenic organisms and floating materials;

d. and reduce the release of settleable organic solids and other oxygen demanding material, nutrients and toxics.

Control Plans designed to meet these objectives were developed for each of the planning areas by the MDC's contractors. Table 3-1 lists the costs and water quality characteristics of the planning areas. The Recommended Plans, and the types of benefits to the area in which they will be implemented, are explained in more detail in the remainder of this Section.

3.2 Neponset River Estuary

The Neponset River Estuary Planning Area contributes to pollution in both the river estuary and Dorchester Harbor. The area is approximately 60 percent residential and five percent industrial with remaining acreage being either open space or commercial/institutional property. Tenean Beach, in Dorchester Harbor, and the shellfish beds in the estuary both experience what the MDC terms "extremely high levels for both total and fecal coliforms, The contractor's survey of the planning area determined that combined sewer and dry weather overflows accounted for over 90 percent of the annual total coliforms. Combined sewer overflow also was a major contributor to floating and suspended solids. The contractor's survey of the in-place sewerage facilities revealed broken or malfunctioning tide gates, malfunctioning regulators, and much solid deposition in the conduits. The fact that downstream interceptors had reduced flow due to sedimentation also compromised this planning area's ability to discharge its waste through normal channels.

Table 3-1.

CSO Planning Area Characteristics

Planning Area	Annualized Capital Costs a/ (MM 1982$)	Annual O & M Costs (MM 1982$)	Total Annualized Costs (MM 1982$)	Receptors	Water Quality Classification	Fecal Col. per 100ml	Total Col. per 100ml	Sus. Solids mg/l	Turb. NTU	BOD_5 mg/l	Total Phos. mg/l	DO mg/l
Inner Harbor c/	14.63	1.97	16.61	Shellfish: Airport	SC T.col ≤ 1000	36- $1.5x10^6$	230- $4.6x10^6$	0-27	1.0-3.1	0.7-92	0.08- 0.86	1.3- 12.2
Constitution Only	0.04	0.01	0.05	Beaches: Constitution	DO ≥ 6.0							
Dorchester Bay c/	4.97	0.37	5.34	Shellfish: Dorchester Bay Beaches: Castle Is. Pleasure B. Carson Malibu Tenean	SB T.col ≤ 700 DO ≥ 6.0	36- 9,300	36- 46,000	3.0- 14.0	0.1	.8-79	0.3-0.6	3.6
Neponset River b/	0.61	0.10	0.71	Shellfish: Neponset Estuary Beaches: Tenean	SB T.col ≤ 700 DO ≥ 6.0	geom mean 6,800	geom mean 38,000	45	1.5	3.2	.22	5.2
Charles River d/	8.87	1.56	10.43	No shellfishing or swimming	C T.col ≤ 1000 DO ≥ 6.0		300- 12,000	0.09- 34.0	0.2- 5.0	0.4- 9.6	0.01- 0.61	0.0- 12.6
Quincy e/	0.25	-0.02	0.27	Shellfish: Quincy Bay Beaches: Wollaston Quincy	SA T.col ≤ 70 DO ≥ 6.0	500- 18,000	800- 34,000	5- 50		1- 5.0		6- 10

a/ Based on 8 1/8 percent interest and a 20 year payback period.

b/ Values for Neponset River are from data gathered in August 1978 (DEQE, 1982).

c/ Values for Dorchester Bay and Inner Harbor are from the CSO Facilities Plans (Camp Dresser & McKee, 1981; O'Brien & O'Gere, 1980).

d/ Values for the Charles River are from data gathered by the MDC (Perullo, 1981).

e/ Values for Quincy are from sampling conducted in June-August 1982.

The Recommended Plan for this area focused initially on dry weather flow abatement, and in this vein the Plan starts with recommendations to fix or replace faulty tide gates, clean and inspect conduits, and re-open the blocked regulators that in their present condition contribute to DWO. Some new conduit and storm drain construction is recommended, both of which are intended to reduce CSOs. The planning area is divided into two subsections, each of which is slated to receive a storage and chlorination facility. Such facilities will store combined sewage until such time that the downstream treatment system can handle it.

According to the contractor's report, this Plan will reduce total coliforms loadings by 96 to 99 percent. The costs are summarized in Table 3-2. Such a reduction will have several benefits, the most calculable being fewer days during which total coliforms exceed the water quality standards for swimming at Tenean Beach. In 1970, the Massachusetts Department of Public Health issued a report on Dorchester Bay beaches indicating that the fecal coliform counts at Tenean Beach were above the guideline of 200 MPN/100 ml for bathing water in 35 to 54 percent of the grab samples and total coliforms exceeded the 1000 MPN/100 ml guideline in 24 to 43 percent of the samples. As a result of the findings regarding these coliform counts and the fact that sewage was clearly being lischarged into Tenean Beach, the Department of Public Health recommended in its 1970 report that the beach be closed for 24 hours after a rainfall of 0.25 inches or more in a 24 hour period. The Recommended CSO Plan will alleviate much of the reported pollution, reduce the need for closing Tenean Beach and, thus, contribute significant recreational (especially swimming) benefits.

Table 3-2. Combined Sewer Overflow Project Costs (1979$)

Neponset River Estuary

Improvement	Capital Costs[a]	O&M Costs[b]
I. Granite Avenue Service Area		
1. Rockwell St. Drain	47,000	120
2. Stockton St. Drain	48,000	120
3. Washington St. Drain	66,000	170
4. Hilltop St. Drain	29,000	77
5. Hallet St. Drain	73,000	180
6. Adams St. Sewer	72,000	180
7. Granite Ave. Truck Sewer	696,000	1,740
8. Davenport Brook and Granite Ave. (Regulator upgrading)	30,000	880
9. Catch Basin Cleaning		25,000
10. Monitoring Program	3,000	12,000
11. Granite Ave. Storage Facility	1,341,000	4,100
12. Net Cost at Deer Island		2,290
II. Port Norfolk Service Area		
1. Chickatawbut St. Pump Station	150,000	4,000
2. Lawley St. Relief Sewer	207,000	520
3. Regulator Rehabilitation	8,000	
4. System Inspection and Cleaning	10,000	5,000
5. Port Norfolk Storage Facility	1,752,000	15,000
6. Net Cost at Deer Island		960
Total Costs		
Total Cost for Granite Avenue Service Area	2,405,000	46,850
Total Cost for Port Norfolk Service Area	2,127,000	25,480
Total Cost for Entire Plan	4,532,000	72,330

[a]Based on June 1979 price levels (ENR 2900) and includes an allowance for engineering and contingencies.

[b]Based on 1979 price levels.

Source: Havens and Emerson, 1980.

The benefits of reducing these coliform counts in the Neponset River Estuary are less clear because the Recommended Plan affects only the mouth of the river. Total coliform loadings upstream of the planning areas are considerable and are unaffected by the Recommended Plan. There are 40 acres of soft shell clam beds in the estuary, most of which are currently classified as grossly contaminated. At present there is not sufficient evidence to predict, with certainty, whether or not the Recommended Plan for the Neponset River Estuary Planning Area will allow those shellfish beds to be opened.

A final benefit of the Recommended Plan has to do with the aesthetic upgrading of the area due to the reduction of odor and floatable solids. In addition to quality of life benefits, such an upgrading may also result in an increase of secondary recreational water use (such as boating and the development of boat ramps and yacht clubs).

3.3 Dorchester Bay

Dorchester Bay is used mainly for swimming, boating and shellfishing. Of all the planning areas it has the highest density of beaches. There are five beaches in the Bay, seven yacht clubs, and 75 acres of shellfish (soft shell clam) beds. Most of the shellfish beds are currently closed to harvesting and four of the beaches are known to exceed total coliform standards after rain storms in the summer.

This degradation of Dorchester Bay's water quality is in large part caused by eleven combined sewer outlets that discharge into waters adjacent to public beaches. Unlike the Neponset River Estuary Planning Area, the Dorchester Bay Planning Area has a wastewater collection system that is in good condition. The contractors discovered "no major structural deficiencies in the regulators, tide gates or sewer manholes.

Several maintenance-related problems were discovered, generally consisting of blockages within the sewers and regulators due to excessive sediment buildup. These maintenance problems and a small number of direct dry weather connections to overflow conduits that were also discovered, result in several dry weather flow dischargers to Dorchester Bay" (Camp, Dresser and McKee, 1981).

The Recommended Plan for the Dorchester Bay Planning Area includes a DWO abatement program and an ongoing program to maintain high operating efficiency in the tide gates and regulators. It also calls for a one and one-half mile consolidation conduit designed to intercept CSOs at the outlet tide gates and to transport the waste to a storage facility. A final part of the plan involves the construction of the two screening and disinfection facilities to protect the Dorchester Beaches during the bathing season. Table 3-3 presents the costs for the Recommended Plan.

According to the contractor's calculations, DWO abatement in the Dorchester Bay Planning Area will result in the attainment of the required water quality standards over the long run. Short-run storm-induced episodes of elevated coliform counts can be avoided by the addition of CSO controls. For all but the most extended heavy storms, the Recommended Plan will reduce total coliform loadings by 98 percent.

In addition the Recommended Plan will greatly reduce the level of floatable solids, oil and grease in Dorchester Bay. Such changes will be particularly beneficial to a planning area that is used primarily for recreation and shellfishing. Reduced coliforms and a reduction in floatable solids will have the direct benefit of increasing swimming and improving

Table 3-3.

Combined Sewer Overflow Project Costs

(1979$)

Dorchester Bay

I. Structural	Capital[a]	O & M[b]
South Boston		
- Consolidation Conduit	9,620,000	
- Storage/Containment Facility	18,380,000	38,000
Dorchester		
- Hoyt St. Regulator Modification	90,000	
- Commercial Point Screening/ Disinfection Facility	3,030,000	22,000
- Fox Point Screening/ Disinfection Facility	2,740,000	21,000
- Pine Neck Creek/ Storm Drain Relocation	2,340,000	
Subtotal	36,200,000	81,000
II. Non-Structural		
Dry weather flow abatement program	100,000	
Post Management Practices	25,000	200,000
Subtotal	125,000	200,000
III. Additional		
Cleaning of CSO Conduits	300,000	
Dredging	40,000	
Landfill at CSO Outlet BOS-090	20,000	
Subtotal	360,000	-0-
Total	36,685,000	281,000

[a]Based on June 1979 price levels (ENR 2900) and includes an allowance for engineering and contigencies.

[b]Based on 1979 price levels.

Source: Camp, Dresser and McKee, 1981.

health through decreasing the number of pathogens in the water. Shellfishing should, over time, increase as bed acreage is opened to harvest.

3.4 Inner Harbor

The Inner Harbor Planning Area has two distinct uses. The majority of the planning area is classified for commercial use while a very small section, Constitution Beach, is classified for swimming. To deal with these divergent uses Table 3-4 is divided to show the costs of attending to the Inner Harbor proper and Constitution Beach separately. The Inner Harbor proper is characterized by industrial, transportation, shipping and energy production uses. The area to the north and east of Logan International Airport has shellfishing and recreational uses similar to the Dorchester Bay. There is swimming at Constitution Beach and there are areas of restricted shellfish harvesting around the airport (MDC, 1982).

According to the contractor for the Inner Harbor Planning Area, over 11 billion gallons of overflow enter the water every year. Seventy-five percent of these discharges are attributable to dry weather overflow and the rest can be accounted for by storm-related discharges. Dry weather overflows are the main cause of elevated coliform counts and floatable solids.

The contractor's report states that the water quality standards set for the Inner Harbor (they are less stringent than those set for the more recreational Dorchester Bay and Neponset River Estuary Planning Areas) can be met with the elimination of dry weather overflows (DWO) and the control of combined sewer overflows (CSO).

Table 3-4.

Combined Sewer Overflow Project Costs

(1979$)

Inner Harbor Planning Area

A. Inner Harbor	Capital Costs [a]	O&M Costs[b]
CSO Consolidated Pipelines		
Boston Waterfront	$5,858,000	N/A
South Boston	5,149,000	
East Boston-Southern Waterfront	6,221,000	
East Boston-Western Waterfront	8,156,000	
East Boston-Lexington Square	980,000	
Chelsea River Waterfront	4,097,000	
Reserved Channel	2,932,000	
CSO Treatment Facilities		
Fort Point Channel	45,542,000	816,000
Somerville	3,450,000	71,200
East Boston-Southern Waterfront	6,894,000	131,000
East Boston-Western Waterfront	6,400,000	48,000
East Boston-Lexington Square	3,575,000	31,700
Chelsea-Pearl Street	3,404,000	66,000
Chelsea Willoughby Street	2,005,000	39,100
Reserved Channel	2,032,000	50,400
Causeway Street	243,000	
Commercial Street	243,000	
Charles River Estuary		5,800
Management Practices		
Tidegate Improvements	250,000	118,000
Regulator Improvements	500,000	118,000
	107,921,000	1,495,300
B. Constitution Beach	315,000	8,700

---

a/ Based on June 1979 price levels (ENR 2900) and includes an allowance for engineering and contingencies.

b/ Based on 1979 price levels.

Source: O'Brien and Gere Engineers, 1980.

The main benefit of this plan is that it will clean up the Inner Harbor by reducing floating solids and thus reduce the consequent aesthetic problems, since the Inner Harbor is not now used for contact recreation, and there are no plans for it ever to be put to that use. Constitution Beach currently meets swimmable standards and the improvements at that site are to ensure that the standards will be maintained. It is difficult to predict if the improvements in water quality will result in more shellfish beds being opened for harvest.

3.5 Charles River Basin

The Charles River Basin includes the Back Bay Fens, the Muddy River, Alewife Brook and the Charles River itself. The basin is mixed fresh and salt water and is used mainly for non-contact recreation, both on the water and at the water's edge. The River is an extremely important and much used recreational source for local residents. Many sailing clubs maintain marinas on the River and every area college and many high schools use the River for rowing and sculling. The entire basin exceeds the water quality standards set for it by the state. Those standards (a rating of "C") allow non-contact recreational use. The main results of the basin pollution are extremely high coliform counts (both total and fecal), odors, floatables, debris and turbidity. The primary objectives of the MDC's efforts are to (Metcalf & Eddy, 1982):

a. reduce excessive levels of bacteriological organisms for public health reasons and remove floatables and turbidity for aesthetic reasons, and

b. remove solids and organic matter to prevent build up of benthic deposits.

In order to meet these objectives, the contractor designed a plan that involves the capture, transport and storage of most of the basin's combined sewer overflows. The plan's costs are presented in Table 3-5.

The Recommended Plan will reduce coliforms, floatable solids and suspended solids (and, therefore, turbidity) in the Charles River Planning Area. Secondary recreation (boating but not swimming) can be expected to increase because of the decrease in objectionable odors and floating debris.

3.6 Quincy Storm Sewers

Another source of pollutant loadings to Boston Harbor is the Quincy storm sewers. The Quincy storm sewers discharge waters with fecal coliform, BOD and TSS concentrations that are higher than levels expected from storm water runoff (Moore, 1980). Storm water contamination can result from cross-connections between sanitary and storm drains. These cross-connections can be due to broken pipes, exfiltration from sanitary sewers in disrepair and illegal "tie-ins" to the storm sewer system, although the latter has not been documented in Quincy. The problem in Quincy is compounded by the fact that North Quincy is relatively flat (especially adjacent to the beach areas) and, therefore, the drains in the area have slopes close to, and in some cases, less than the recommended minimums. This tends to cause blockages in the sanitary system and surcharges and exfiltration of sewage results, especially where pipes are cracked or have loose joints (Moore, 1977). A factor which increases the frequency of surcharging is the excessive infiltration and inflow into the

Table 3-5.

Combined Sewer Overflow Project Costs (1979$)

Charles River Basin

	Design Package	Capital Costs a/	O&M Costs b/
1.	Phase I In-System Modification	510,000	5,000
2.	Consolidation and Rebuilding of Boston Gatehouses #1 and #2	6,650,000	87,000
3.	Grit Removal and In-System Storage at Beacon Street and Charlesgate East with Phase II In-System Modification to MDC Fens Gatehouse	4,900,000	72,000
4.	Restoration of the Fens with Phase II In-System Modifications in the Muddy River Sub-area	2,000,000	20,000
5.	Connection from Stony Brook and Old Stony Brook Conduits to the Boston Main Drainage Relief Sewer	1,060,000	187,000
6.	Grit and Sludge Removal from Stony Brook and Old Stony Brook Conduits	4,750,000	
7.	Stony Brook Screening Disinfection, and In-System Storage Facility near Tremont and Gurney Streets	7,500,000	360,000
8.	Stony Brook In-System Storage Facility and Base Brook Pumping Station at Green Street	10,400,000	116,000
9.	Phase II In-Line Storage Tannery Brook	5,900,000	14,000
10.	Surface Storage of Canterbury, Bussey and Stony Brooks	1,260,000	50,000

Table 3-5 (continued).

Combined Sewer Overflow Project Costs (1979$)

Charles River Basin

Design Package	Capital Costs a/	O&M Costs b/
11. St. Mary's Street In-System Storage	335,000	2,000
12. Concord, Rindge and Mass. Aves. Industrial Sewer Separation	3,600,000	
13. St. Mary's, Street Diversion to Cottage Farm Facility	2,800,000	4,000
14. Phase III In-System Modifications	360,000	11,000
15. Brighton-Allston Phase II In-Line Storage	10,850,000	88,000
16. Brighton-Allston Phase III Off-Line Storage	2,500,000	56,000
Management Practices and Monitoring Program	40,000	108,000
Total	65,415,000	1,180,000

a/ Based on June 1979 price levels (ENR 2900) and includes an allowance for engineering and contingencies.

b/ Based on 1979 price levels.

Source: Metcalf and Eddy, 1982.

sanitary system. Quincy is the last (i.e., downstream) city in the South Metropolitan Sewer District so that excessive flows from as many as 20 cities are channeled through Quincy on their way to the Nut Island Treatment Plant. It has been estimated that as much as 57% of the flow reaching Nut Island during a rainstorm is due to infiltration/inflow (Moore, 1981). Thus, the problem of correcting stormwater contamination in Quincy involves repair and rehabilitation of both the sanitary and storm sewer systems.

Several investigations and improvements have been undertaken in recent years to locate sources of contamination of storm drains, in particular in order to reduce total and fecal coliform levels at Wollaston Beach to within acceptable levels, as determined by State standards (Moore, 1980). In addition, studies of the infiltration/inflow problem are continuing (Moore, 1981). It should be noted that other sources of contamination of the area's beaches include the Nut Island sewage treatment plant discharges and, in particular, recurring by-passes from both Nut Island and Moon Island.

Although estimates of treatment costs for the Quincy storm sewers comparable to those for the CSO planning areas are not available, recent studies give an indication of the order of magnitude of the costs involved (Table 3-6).

3.7 Summary of Options

The annual cost of implementing all five of the CSO and Storm Sewer plans is about $30 million (1982$). The costs of implementing portions of the plans or only some of the plans will, of course, be less.

Table 3-6. Potential Storm Sewer and Infiltration/Inflow Project Costs for City of Quincy (1981$)

Recommended Facility	Costs
Sewer System Evaluation Survey and Rehabilitation of Sewers	417,000
Construction of Relief Interceptors	
North Quincy	204,000
West Quincy	844,000
Quincy Point Diversion/ Relief Interceptor	132,000
Town River Bay Interceptor	703,000
Rehabilitation of Quincy Point Pump Station	40,000
Construction of Furnace Brook Emergency Relief Lift Station (MDC)	180,000
Total Capital Costs	2,520,000
Annual O & M Costs	-22,000

Note: Many problems remain and the city of Quincy has authorized a new engineering study so that these estimates of costs are preliminary only. They are taken from Table 8, Moore (1981), and do not include land and easement acquisition costs. The annual operation and maintenance costs are expected to decrease as a result of the infiltration/inflow removal program.

In order to gain swimming benefits at all beaches and shellfishing benefits at many of the currently closed shellfish beds in Boston Harbor, the Constitution part of the Inner Harbor plan, the entire Neponset River Estuary and Dorchester Bay Plans, and the Quincy plan must be implemented. Such a treatment option would cost more than $6.3 million a year (in 1982$), and it would affect neither the Charles River Basin nor the Inner Harbor proper.

Another option might be to implement only the Dorchester Bay and Neponset River Estuary plans. This would cost about $6 million (in 1982$) annually, but while making swimming safe in Dorchester Bay, it might compromise the water quality at Constitution Beach and Quincy Bay beaches in the long run as the population of these areas increases and wastewater discharges increase.

Table 3-7 shows the annual costs of the CSO and storm sewer options along with the approximate percentage reduction in pollutant loadings, including fecal coliform, floatable and suspended solids, and oil and grease. The top part of the table presents the four CSO plans as designated by the MDC. The bottom part shows the options used in the benefit-cost analyses in this study. The options as defined in the lower half of the table correspond more appropriately with the benefit estimates associated with the uses of the Harbor. For example, all the swimming and shellfishing uses affected by the CSOs (and therefore the corresponding benefits estimates) can be captured by including only the Constitution Beach portion of the Inner Harbor Plan plus the Dorchester Bay, Neponset River, and Quincy plans. The numbers in the table reflect incremental increases in annual costs.

Table 3-7. Incremental Costs and Potential Reductions

in Pollutant Loadings for the CSO Options

(Millions 1982$)

Treatment Alternative/ Receptor	Annualized Capital Cost a/	Annual O&M Cost	Total Annual Cost	Percentage Reduction in Pollutant Loadings b/
MDC PLANNING AREA DESIGNATION				
Inner Harbor				
a) Including Constitution	14.63	1.97	16.61	
b) Constitution only	0.04	0.01	0.05	50 - 99
Dorchester Bay	4.97	0.37	5.34	70 - 99
Neponset River	0.61	0.10	0.71	60 - 98
Charles River Basin	8.87	1.56	10.43	65 - 100
Implementation of all MDC designated CSO plans	35.44	4.00	33.39	50 - 100
STUDY AREA DESIGNATION				
Inner Harbor Constitution Beach only	0.04	0.01	0.05	50 - 99
Dorchester Bay/ Neponset River	5.59	0.47	6.06	60 - 99
Quincy Storm Sewers c/	0.27	-.02	0.25	60 - 99 d/
Above three plans combined	5.90	0.46	6.36	50 - 99
Charles River	8.87	1.56	10.43	65 - 100

References

Metropolitan District Commission, April 1982, Combined Sewer Overflow Project: Summary Report on Facilities Planning, Boston, MA.

Massachusetts Department of Environmental Quality Engineering, May 1982, Neponset River 1978 Water Quality Data, Publication No. 12808-39-35-5-82-CR, Boston, MA.

Ferullo, Alfred, Paul DiPietro, and Robert Schaughnessy, June 1981, Charles River Articifial Destratification Project, Metropolitan District Commission, Boston, MA.

Havens & Emerson, Inc., September 1980, Combined Sewer Overflow Facilities Plan for the Neponset River Estuary, Boston, MA.

Massachusetts Department of Public Health, 1970, Report of the Massachusetts Department of Public Health to the Interagency Task Force on the Survey of the Dorchester Bay Beaches, Boston, MA.

Moore Associates, Inc., H.W., 1977, Drainage Contamination Study for North Quincy, Quincy, Massachusetts, Boston, MA.

Moore Associates, Inc., H.W., 1981, Facility Plan for Water Pollution Control, Volume I, Quincy, Massachusetts, Boston, MA.

Moore Associates, Inc., H.W., 1980, Wollaston Beach Exploration/Remedial Program Regarding Storm Water Contamination, Boston, MA.

Camp Dresser & McKee, Inc., October 1981, Report on Combined Sewer Overflows in the Dorchester Bay Area.

O'Brien & Gere Engineers, Inc., June 1980, Combined Sewer Overflow Project Inner Harbor Area Facilities Plan.

Metcalf & Eddy, Inc., September 13, 1979, Application for Modification of Secondary Treatment Requirements for Its Deer Island and Nut Island Effluent Discharges into Marine Waters, for the Metropolitan District Commission, Boston, MA.

Metcalf & Eddy, Inc., May 1982, Final Report to the Metropolitan District Commission on Combined Sewer Overflows; Charles River Basin Facilities Planning Area, Boston, MA.

Section 4

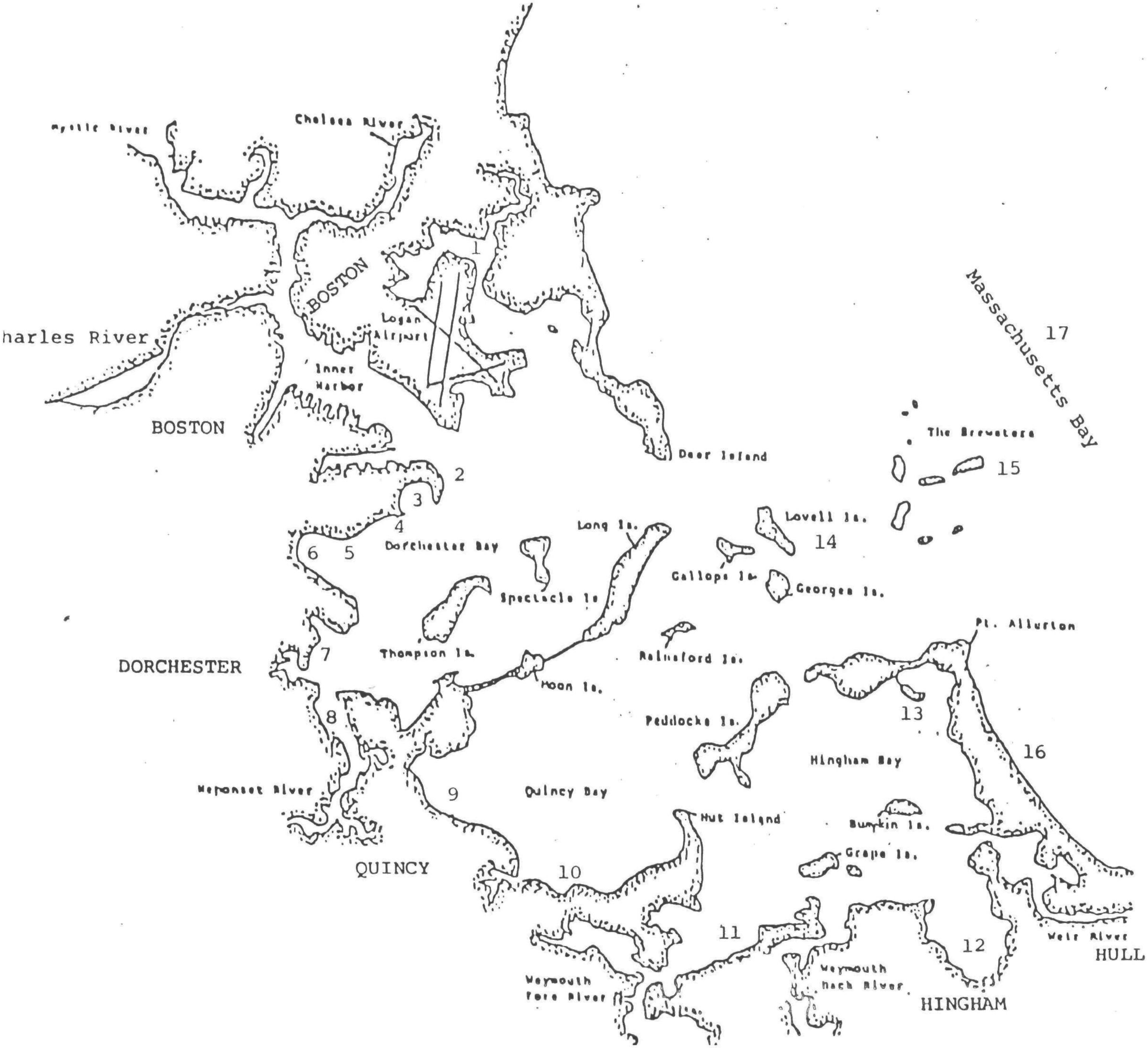
Water Quality Impacts

To estimate the change in water quality that is expected to take place under the various options for reducing pollutant loadings it is necessary to take into account the change in loadings, the dispersion pattern in the Harbor from the point of discharge to the areas where recreation and fishing take place (receptor areas), and the current ambient water quality in these areas. The reception areas defined for the purposes of this study are shown in Figure 4-1. Pollutant loadings continue under all treatment options but at rates less than the current ones. Thus, percent improvements in water quality are related to percent reductions in pollutant loadings under the various options. The changes experienced under any of the options are not expected to be in the form of new dispersion patterns but rather are expected to be concentration reductions in the water column. The changes are incremental ones, evaluated in relation to current loadings and current ambient quality.

4.1 Water Quality Impacts of STP Dischargers

To assess the impact of STP discharges in Boston Harbor it is important to know how such discharges are dispersed throughout the Harbor. Since discharges to the Harbor are subject to diverse and variable conditions, the water quality throughout the Harbor is not uniform. A few models have been developed to quantitatively explain some of these variations and to correlate

Figure 4-1. Receptor Areas for the Boston Harbor Study



1. Constitution Beach
2. Castle Island
3. Pleasure Bay
4. City Point
5. L&M Streets Beach
6. Carson Beach
7. Malibu Beach
8. Tenean Beach
9. Wollaston Beach
10. Quincy Town Beaches
11. Weymouth Bay
12. Hingham Harbor
13. Hull Bay
14. Outer Harbor Islands
15. Brewsters Islands
16. Nantasket Beach
17. Massachusetts Bay

STP discharges with water quality. The DISPER model, developed at Massachusetts Institute of Technology, was designed specifically to quantify the dispersion of STP discharges into Boston Harbor. This model was used in the assessment of a deep ocean outfall in the MDC's application for a waiver to secondary treatment (Metcalf and Eddy, 1979). We use the dilution ratio results to predict relative changes in water quality but use ambient water quality data from other sources.

The DISPER model (and the associated CAFE model) relies largely on water movement (currents) to describe dispersion.[a] It models BOD only and predicts volumetric inflows and outflows from the Harbor. Whether pollutant loadings move exactly as does the water is unknown because settlement and decomposition in transport, propensities of marine organisms to assimilate wastes, etc., are not precisely understood. Assumptions regarding settling rates, decay rates, biological uptake, and chemical reactions are employed in running DISPER. This model is useful in comparing relative dispersion differences for the different STP options while precise, absolute values predicted by DISPER may not be as reliable. It was with this in mind that the maps of dilution ratios in Section 2 were developed based on the DISPER model (Figures 2-4, 2-5, and 2-6).

In order to use the dilution ratios produced by DISPER to assess water quality impacts, current water quality must be known. The Boston Regional Office of the Environmental Protection Agency (Region I) has recently undertaken to bring together all water quality sampling data collected in the Harbor since 1968. They have stored the data in a computer system called the

---

[a] See Appendix A.2 for a further description of this model.

Boston Harbor Data Management System and, in December 1983, could produce computer-generated maps with statistically-averaged data for various points throughout the Harbor and adjacent waters. The information from this system that we used in the analysis below includes data on fecal coliform, BOD_5, and total suspended solids averaged over the years 1968 to 1983 at the receptor sites of interest to this study.

To calculate the water quality impacts of reduced pollutant loadings under the various STP options, the change in effluent concentrations were multiplied by the dilution ratios at the various receptor sites (Table 4-1). The reduction was compared to current ambient quality to calculate a percentage change in water quality. This simplified approach is clearly not accurate if absolute values for water quality are desired. The nature of both the current water quality data and the limitations of the dispersion model preclude any attempt to predict absolute values. However, for the purposes of our analysis percentage changes in water quality with a range to indicate the degree of uncertainty is sufficient.

4.2 Water Quality Impacts of Combined Sewer Overflows

The individual contractor reports on combined sewer overflows included modeling for water quality impacts. In those reports the impact was evaluated using both statistical and time-varying models. The statistical modeling was used to produce a long-term picture of the quality of water in different segments of the harbor. The time-variable model produced dynamic changes in water quality over a finite period of time in order to predict the results of discrete storm events. Total coliform counts were used in both

Table 4-1. Effluent Concentrations and Dilution Ratios Used in the Water Quality Impact Analysis

EFFLUENT CONCENTRATIONS [a]

Pollutant	Existing Facilities: Deer Island[b]	Existing Facilities: Nut Island	Deep Ocean Outfall Option	Secondary Treatment Option
Fecal Coliform (MPN/100 ml)	1500	1500	1500	1500
BOD_5 (mg/l)	127.6	105	115	30
TSS (mg/l)	121	110	86	30

[a] Values as summarized in EPA (1983) and Metcalf & Eddy (1979).

[b] Includes sludge discharged into Presidents Roads.

DILUTION RATIOS [c]

Receptor Area	Outfall Location: Presidents Roads (Deer Island)	Outfall Location: Nantasket Roads (Nut Island)	Outfall Location: Ocean Outfall
Constitution Beach	500	---	---
Dorchester Bay	100-200	---	---
Quincy Bay	---	50-100	---
Hingham Bay	---	100-200	---
Outer Harbor Islands	50	50	---
Brewsters Islands	500	500	200
Nantasket Beach	---	500	200
Massachusetts Bay	1000	1000	200

[c] From DISPER contour maps.

the statistical and time-variable models. Although the models predict actual total coliform counts for both existing conditions and under the recommended plan, we state the results in terms of relative percentage changes both to indicate the degree of uncertainty and as sufficient for our purposes.

The studies of the Quincy sewer systems did not model water quality. In this study we have assumed the situation to be similar to the Dorchester Bay area in this regard.

4.3 Estimated Water Quality Impacts of the STP and CSO Treatment Options

Table 4-2 presents the results of the water quality impact analyses. The entries are ranges of predicted percentage change in water quality due to each treatment option at each receptor site. Table 4-3 presents best-guess point estimates for the same options and receptor sites. (Appendix A gives details for these calculations.) These were compiled for use in several of the benefit estimation approaches. Again it should be noted that limitations of both data and methodology preclude estimation of absolute changes in water quality. However, relative percentage changes are adequate for the benefit estimation procedures to be used in the remaining sections of this report.

This report investigates pollution due to sewage treatment plant discharges and combined sewer overflows. Other point and non-point sources exist which were not included in the scope of this report. They include the large amount of shipping and boating in the Harbor, run-off from urban areas not collected by the sewer system and potential resuspension of pollutants from sediments in the Harbor. Thus, our estimates of water quality changes do not reflect complete reduction of pollutant levels because of these other sources whose impact is, essentially, unknown at this time.

Table 4-2. Estimated Water Quality Impacts of the CSO and STP Treatment Options

Receptor Area	Percent Pollution Reduction by Treatment Option		
	Combined Sewer Overflow/ Storm Sewer	Deep Ocean Outfall	Secondary Treatment
Constitution Beach	50 to 80	5 to 10	0 to 5
Dorchester Bay	60 to 90	10 to 25	5 to 15
Quincy Bay	60 to 90	10 to 20	10 to 20
Hingham Bay	--	15 to 40	15 to 40
Outer Harbor Islands	--	60 to 90	30 to 80
Brewsters Islands	--	-10 to -15	30 to 40
Nantasket Beach	--	-5 to -10	0 to 5
Massachusetts Bay	--	-35 to -45	15 to 20
Charles River	50 to 80	--	--

Note: Positive figures denote improved water quality. Negative figures denote degradation in water quality.

Source: See Appendix A for details of the calculations.

Table 4-3. Estimates of Pollution Reduction at Receptor Sites in Study Area (Point Estimates)

	Percent Pollution Reduction by Treatment Option		
	CSO/Storm Sewer	Deep Ocean Outfall	Secondary Treatment
Constitution	70	10	5
Dorchester/Neponset Bay			
Castle Island	80	10	10
Pleasure Bay	80	10	10
Carson	80	10	10
Malibu	80	10	10
Tenean	80	10	10
Wollaston	80	10	10
Quincy	80	10	10
Weymouth	--	30	30
Hingham	--	30	30
Hull	--	30	30
Outer Harbor Islands	--	80	70
Brewsters Island	--	-15	40
Nantasket Beach	--	-10	--
Massachusetts Bay	--	-40	20
Charles River	70	--	--

Note: Positive figures denote improved water quality. Negative figures denote degradation in water quality. Based on Table 4-2.

References

Environmental Protection Agency, June 30, 1983, Analysis of the Section 301 (h) Secondary Treatment Waiver Application for Boston Metropolitan District Commission, Office of Marine Discharge Evaluation, Washington, DC.

Metcalf & Eddy, Inc., September 13, 1979, Application for Modification of Secondary Treatment Requirements for Its Deer Island and Nut Island Effluent Discharges into Marine Waters, for the Metropolitan District Commission, Boston, MA.

Section 5

Approaches to Measuring Benefits from Water Quality Improvement

Estimates of changes due to changing ambient pollutant levels are the basis for benefit measurements. These changes include effects on human health, human activities, such as recreation, and the availability of goods and services. The economic value individuals place on the reduction of the adverse effects due to pollutants is the measure of benefits. As will be seen throughout this report, for some effects, such as ecological changes, current efforts can only, at best, delineate the physical changes; for others, either a partial or full economic evaluation is possible. This section describes the economic theory appropriate to measuring such benefits and the classification scheme used in this study.

5.1 Theoretical Concepts

The benefits of improved water quality resulting from implementation of pollution control options can be classified in many ways. One way is to divide them into benefits to users of the water resource and benefits to non-users, or intrinsic benefits, as presented in Table 5-1. Potential benefits from water pollution abatement accrue from current users or from intrinsic values. Current user benefits stem from either indirect use (near-stream activities that are enhanced by the water body such as picnicking, jogging, hiking or viewing), direct use of water resources for

Table 5-1. A Spectrum of Water Quality Benefits

Potential Water Quality Benefits	Current User Benefits	Direct Use	In Stream	Recreational--fishing, swimming, boating, rafting, etc.
				Commercial--fishing, navigation
			Withdrawal	Municipal--drinking water, waste disposal
				Agricultural--Irrigation
				Industrial/Commercial--cooling, process treatment, waste disposal, steam generation
		Indirect Use	Near Stream	Recreational--hiking, picknicking, birdwatching, photography, etc.
				Relaxation--viewing
				Aesthetic--enhancement of adjoining site amenities
	Intrinsic Benefits	Potential Use	Option	Near-term potential use
				Long-term potential use
		No Use	Existence	Stewardship--maintaining a good environment for everyone to enjoy (including future family use--bequest)
				Vicarious consumption--enjoyment from the knowledge that others are using the resource.

Source: Adapted from RTI, 1983.

instream purposes (recreational and commercial), or withdrawal purposes (municipal, agricultural, industrial/commercial). Intrinsic benefits are based on non-user valuation of the existence of the resource, and on the potential future use of the resource. Since the distinction between these types of benefits is not always clear-cut and since many of the analytical techniques used to measure benefits cover more than one of these types of uses, we have chosen to reclassify the water uses according to the economic entity to which the benefits accrue (see Table 5-2). Here, benefits flow to households as recreators in, on or near the water and as consumers, who benefit directly or indirectly (secondary benefits) from the increased economic activity in the primary sectors, and to producers who use the water resources. The benefits that will accrue from pollution abatement in Boston Harbor are noted with an asterisk in Table 5-2.

Most of the methodologies used to measure the benefits to society from environmental improvements are based on the theory of welfare economics and the concept of willingness to pay (WTP). This economic theory is founded on the principle that the "demand" for water quality is the sum or aggregate of how much individuals of a society would be willing to pay to receive additional increments of improved water quality. The concept of willingness to pay has been translated into other alternative theoretical measures of willingness to pay, including consumer surplus, compensating variation, and equivalent variation. In simple terms, consumer surplus is the difference between what individuals are willing to pay and what they actually pay for a good. Figure 5-1 illustrates this individual demand function which

---

a/ The following discussion is based on material discussed and presented in RTI, 1983.

Table 5-2. Economic Benefit Categories

(Alternative Typology)

I. Benefits to Households

A. Recreation Benefits:

1. Swimming*	Direct Use
2. Fishing*	Direct Use
3. Boating*	Direct Use
4. Aesthetic*	Indirect Use
5. Near-stream recreation*	Indirect Use
6. Option value*	Potential or non-use
7. Existence*	Potential or non-use

B. Consumption Benefits:

1. Commercial Fisheries*
2. Health
   a. Swimming*
   b. Food Consumption*

C. Ecological*

II. Benefits to Producers:

A. Commercial Fishing*

B. Municipal drinking and wastewater

C. Agricultural

D. Industrial

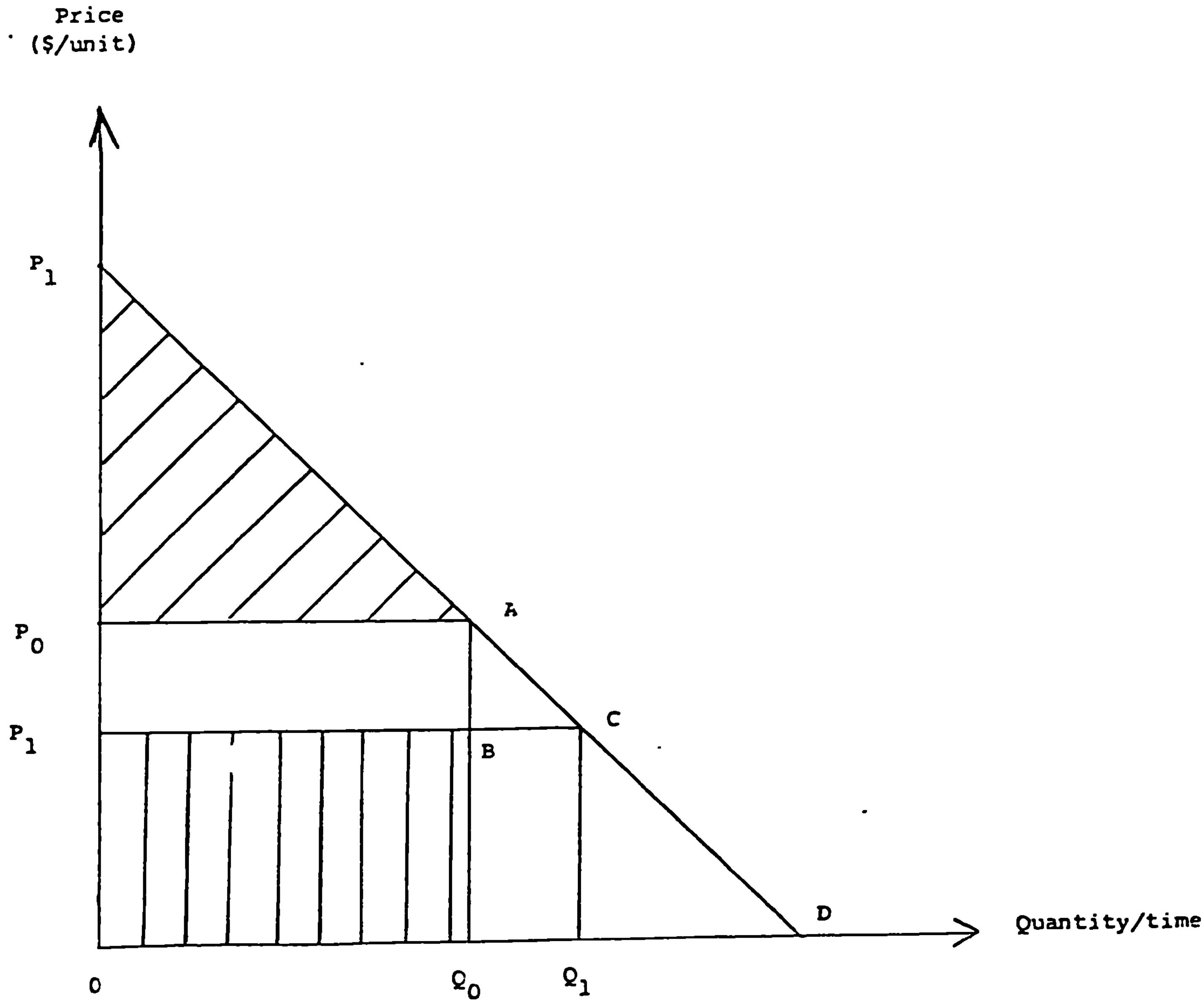
E. Navigational

III. Secondary Effects*

---

* Benefits from pollution abatement in Boston Harbor.

Figure 5-1. The Demand Function and the Consumer Surplus Welfare Measure.



Source: RTI, 1983

describes, for any commodity X, the maximum amount an individual would be willing to pay for each quantity of X.[a] The downward slope of the curve illustrates that individuals are willing to buy more of commodity X at lower prices than at higher prices. The simple two-dimensional diagram in Figure 5-1 assumes all other factors that might influence demand--income, the prices of related goods, etc.--do not change. At price P_0 the individual will purchase Q_0 of X and make a total expenditure of P_0AQ_00. Because the demand curve measures the individual's maximum willingness to pay for each level of consumption, the total willingness to pay for Q_0 can be derived: total expenditures plus the triangle P_jP_oA. The difference between what individuals actually pay with a constant price per unit and the amount they are willing to pay is defined as the consumer surplus.

As a dollar measure of individual welfare, however, consumer surplus is not ideal. The most direct way of understanding its limitations is to consider the measurements underlying an ordinary Marshallian demand function. An individual's demand function describes the maximum an individual with a given nominal income would be willing to pay for each level of consumption of a particular good. Specifically, if the price paid changes, it will affect not only what the individual can purchase of this good, but also the purchases of all other commodities through its effect on the remaining disposable income. Thus, movement along a conventional demand function affects the level of satisfaction an individual will be able to achieve with a given income. For example, suppose the price of hypothetical good X declines to P_1. The individual can purchase the same quantity of X at its new price as indicated in Figure 5-1 by the area OP_1BQ_0 and have income remaining, as given by P_1P_0AB, to purchase more X or more of other goods and services. The movement to a consumption level of OQ_1 describes the increased selection of X under the new price. This change leads to a higher utility level because more goods and services can be consumed with the same income. For consumer surplus to provide an "ideal" dollar measure of individual well-being, however, the appropriate area under an Hicksian income-compensated demand curve rather than an ordinary Marshallian demand curve, should be used. Nevertheless, ordinary Marshallian demand curves are much easier to estimate, and Willig (1976) has shown that they provide a reasonably close approximation to the "ideal" measure.

The four "ideal" Hicksian welfare measures are summarized below (Hicks, 1943):

- Compensating variation (CV)--the amount of compensation that must be taken from an individual to leave him/her at the same level of satisfaction as before the change.
- Equivalent variation (EV)--the amount of compensation that must be given to an individual, in the absence of the change, to enable him/her to realize the same level of satisfaction he/she would have with the price change.
- Compensating surplus (CS)--the amount of compensation that must be taken from an individual, leaving him/her just as well off as before the change if he/she were constrained to buy at the new price, the quantity of the commodity he/she would buy in the absence of compensation.
- Equivalent surplus (ES)--the amount of compensation that must be given to an individual, in the absence of the change, to make him/her as well off as he/she would be with the change if he/she were constrained to buy at the old price the quantity of the commodity he/she would buy in the absence of compensation.

If commodity X in Figure 5-1 represents environmental quality, then in order to measure environmental improvement benefits it is necessary to measure the marginal benefit curve for environmental quality, estimate the levels of environmental quality before and after environmental changes, and then calculate the area under the marginal benefit curve. This is difficult to do because there exists no explicit market for environmental quality. Therefore, a variety of alternative techniques to measuring willingness to pay for improvements in environmental quality have been developed. These techniques fit three major categories: (1) the specific damages approach; (2) the implicit market approach; and (3) the hypothetical contingent valuation approach. The specific damages approach involves monetizing a physical measure of damage per unit receptor per pollutant and combines this with the amount of receptor population. This measure is considered a crude, lower-bound proxy for willingness to pay. The implicit market approach stems from the observation that perceptions and values of environmental quality are reflected in individuals' behavior in markets related to environmental quality, such as property values or travel costs to recreational sites. The contingent valuation approach relies on surveys or bidding experiments which elicit direct measures which are contingent on the hypothetical framework from which individual valuations are obtained.

The most fundamental approach to benefit valuation is the implicit market approach, or supply/demand analysis because it enables the calculation of consumer and producer surplus at an equilibrium. The demand for water resources of a particular quality arises from a desired use activity--uses for recreational activities, industrial water uses, withdrawals for supplies, etc. Each of these uses requires a certain quality of water and the demand depends on potential uses at a given geographic location. To evaluate the effects of changes in water quality, demand for a use activity must be calculated. It is not always possible, however, to conduct demand curve estimation for benefit calculations. In reality, only a partial form of demand analysis can be done. Moreover, the success (or reliability of the estimate) of the analysis varies by benefit category.

For an in-depth discussion of these issues and methodologies that are used to estimate economic benefits from pollution abatement see Freeman, The Benefits of Environmental Improvement (1979), and Air and Water Pollution Control: A Benefit-Cost Assessment (1982); Feenberg and Mills, Measuring the Benefits of Water Pollution Abatement (1980); and Research Triangle Institute, A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements, (1983).

5.2 Study Methodology

Our strategy in this study is to employ methods developed by previous researchers and to compute benefits for each category using a variety of estimation techniques whenever possible.

The various categories of effects (or beneficial use classes) are summarized in Table 5-3. The table also indicates the approach which has been used to estimate the effect/benefit, and an evaluation of the reliability and availability of the methodology and data.

Table 5-3

Benefit Categories and Methodologies for Boston Harbor Study Area

Benefit/Effect	Benefit Estimation Approach	Reliability of Methodology	Reliability/ Availability of Data
<u>Recreation</u>			
Swimming	o Travel cost (logit model)	excellent	excellent
	o Regional participation	good	fair to good
	o Beach closings cost savings	fair	fair to good
Boating	o Regional participation	fair	fair
Fishing	o Regional participation	fair	fair
<u>Health</u>			
Swimming	o Dose-response function (incidence of disease)	excellent	good
Food consumption	o Dose-response function (incidence of disease)	good	fair to good
<u>Commercial fisheries</u>	o Demand and supply functions	good	poor
<u>Intrinsic Benefits</u>	o Contingent valuation survey	fair	fair
	o Direct % of recreation benefits	good	good
<u>Ecological</u>	o No approach available to apply a dollar value for benefits	--	--
<u>Secondary Effects</u>	o Input-output multipliers	fair	fair

References

Feenberg, Daniel and Edwin Mills, 1980. Measuring the Benefits of Water Pollution Abatement, Academic Press, New York, NY.

Freeman, A.M. 1979. The Benefits of Environmental Improvement, Johns Hopkins University Press, Baltimore, MD.

Freeman, A.M., 1982. Air and Water Pollution Control: A Benefit-Cost Assessment, John Wiley and Sons, Inc., New York, NY.

Hicks, John R., 1943. The Four Consumers' Surplus, Review of Economic Studies, 11:31-41.

Research Triangle Institute, 1983. A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvement, Research Triangle Park, North Carolina, EPA.

Willig, Robert D., 1976. Consumer Surplus Without Apology, American Economic Review, 66:589-597.

Section 6

Recreation Benefits

The recreation benefits of improving water quality in Boston Harbor are many. Boston Harbor is surrounded by a major metropolitan area of 2.8 million people and provides a setting for many diverse water uses including boating, sailing, canoeing, fishing, swimming and beach activities. In addition, in recent years the harbor has become an aesthetic focal point for water-enhanced recreation activities such as picnicking, bicycling, camping, hiking and sight-seeing. Figure 6-1 shows the various locations (called receptor sites) of these water uses.

Although the CSOs and the STPs affect some of the same harbor areas of the study, in general the receptor sites are primarily affected by one or the other source. The CSOs affect recreation areas closest to the shore and, thus, have the greatest impact on swimming and shore-related fishing and boating. Of all the CSO planning areas, Dorchester Bay is influenced the most because of the great concentration of CSOs and beaches in the bay. The Quincy storm sewers affect water quality at local town beaches and Wollaston Beach. The Charles River CSOs have a major impact on boating. This area is discussed separately in Section 11 because of differences in data bases and the nature of the water resources.

The areas primarily affected by the STP discharges are the waters and islands surrounding the STP outfalls. Beaches in the towns of Quincy,

Figure 6-1. Receptor Areas for the Boston Harbor Study

1. Constitution Beach
2. Castle Island
3. Pleasure Bay
4. City Point
5. L&M Streets Beach
6. Carson Beach
7. Malibu Beach
8. Tenean Beach
9. Wollaston Beach
10. Quincy Town Beaches
11. Weymouth Bay
12. Hingham Harbor
13. Hull Bay
14. Outer Harbor Islands
15. Brewsters Islands
16. Nantasket Beach
17. Massachusetts Bay

Weymouth, Hingham and Hull and the Boston Harbor Islands are the swimming areas primarily affected by the STPs.

The Boston Harbor Islands--Slate, Bumpkin, Grape, Georges, Lovells, Gallups, Deer, Long, Rainsford, Moon, Thompson, Spectacle, Sheep, Peddocks, and the Brewsters--are a unique natural resource in a metropolitan area possessing only one-half of the recommended minimum acreage of open space per thousand population. The Islands offer a wide range of activities such as boating, swimming, picnicking, fishing, hiking, camping, scuba diving, and historic sight-seeing. Many of the islands have limited recreational facilities which restrict current and potential visits. Poor water quality, however, is also a major factor restricting recreational activities. Effluent from Deer and Nut Island sewage treatment plants seriously degrades water quality around the Islands, particularly discouraging swimming and fishing. Assuming that the planned recreational facilities were constructed, then upgrading the plants and/or discharging the effluent into the ocean would lead to a significant improvement in water quality, which would lead to a corresponding increase in both frequency of participation and total number of visitors.[a/]

Fishing and boating are also affected by the STPs since a large percentage of these activities take place in the outer harbor study area rather than on or near the shore. Participation in all boating--sailing, motor boating, canoeing and windsurfing--and fishing activities in Boston Harbor is expected to increase with decreases in water pollution levels.[b/]

---

a/ The exception to this assumption is the Brewsters Islands and Nantasket Beach, which are expected to be negatively influenced by the ocean outfall option.

b/ The degradation of water quality in Massachusetts Bay under the ocean outfall option is expected to primarily affect commercial fishing.

6.1 Data Needs and Data Bases

The data needed to estimate recreational activity in these various areas and to relate the uses to changes in water quality come from a variety of sources. This section discusses the data bases used to estimate recreation benefits. It is followed by a discussion of the various methodologies which have been applied to the Boston Harbor case to arrive at a range of benefit estimates for each separate benefit category.

6.1.1 Swimming Attendance

Seven of the beaches managed by the Metropolitan District Commission (MDC) are affected by CSOs and/or STPs in the study area: Constitution, Castle Island, Pleasure Bay (including City Point), Carson,[a] Malibu, Tenean, and Wollaston. Nearby cities and towns also have small neighborhood beaches which are affected by pollution control sources. The cities of Quincy, Weymouth, Hingham and Hull recognize ten beaches besides Wollaston for water quality collection purposes. In addition, swimming occurs on an informal basis on many of the eleven Boston Harbor Islands. Rough estimates put recent seasonal attendance of all these affected beaches at 4.0 million people (see Table 6-1). Unfortunately, neither the MDC, the towns, nor the Massachusetts Department of Environmental Management (DEM) keep attendance records or make official counts during the season. In addition, people swim at the beaches during warm weather in the spring and fall, even though they are not officially open. Information from a 1975 recreation survey (Binkley and Hanemann) and from the MDC indicate that some of the Boston area beaches

---

[a] L and M Street Beach, part of Carson Beach, is managed by the City of Boston.

Table 6-1. Seasonal Swimming Supply

Current Seasonal Beach Attendance	Seasonal Capacity [a]	Seasonal Excess Supply [b]
Constitution 325,000	582,780	257,780
Dorchester/Neponset 590,000	5,044,878	4,454,878
Castle Island 15,000	291,390	276,390
Pleasure Bay 175,000	1,548,155	1,373,155
Carson 100,000	1,899,774	1,799,774
Malibu 150,000	632,449	482,449
Tenean 150,000	673,110	523,110
Wollaston 2,750,000	4,595,976	1,845,976
Quincy 158,900	320,568	161,668
Weymouth 105,820	763,680	657,860
Hingham 22,200	355,200	333,000
Hull 66,000	532,800	466,800
Nantasket Beach 3,035,000	[c]	[c]

[a] Based on 40 ft^2 per person; turnover of 3 times per day; 29.6 peak user days per season. Except Wollaston Beach with four times per day turnover and 39.4 peak user days per season. (Derived from US Department of Interior, 1970.)

[b] Excess supply = (Capacity) minus (Current attendance).

[c] Not applicable since expect degraded or unchanged water quality.

Source: See Appendix B, Table B-1.

Note: Brewsters Islands are omitted because most of the recreational activity is fishing and boating, and Massachusetts Bay is omitted because the primary activity is commercial fishing.

draw people from many parts of the Boston Metropolitan area. Other beaches appear to be used almost exclusively by people from a nearby section of the city, such as Carson Beach by South Boston residents and Constitution Beach by East Boston residents.

Attendance data used for calculating swimming benefits were estimated by MDC personnel and by recreation and park department officials in Quincy, Weymouth, Hingham, and Hull. We also compared attendance figures reported by the MDC in the 1975 Binkley and Hanemann study along with attendance figures generated from a survey used in their study. This range of values can be found in Table B-1, Appendix B. Data on beach acreage and/or linear feet of beach/shoreline was also supplied by the MDC and municipalities and was used to develop a range of beach capacities for each affected area based on national recreation standards. Estimates for beach capacity and beach attendance numbers are presented in Table 6-1. These attendance and capacity figures are used in several approaches to calculating swimming-related benefits in this report. The accuracy of these methods is linked to the accuracy of the recreation data.

Other factors could also act to limit the increased participation predicted as a result of water quality improvement. They include crowding and congestion, available parking facilities, presence of jellyfish and, particularly for Boston Harbor, cold temperatures of the air and water. Although these effects can be significant, the first three factors were not considered here because of insufficient data. The effects of air and water temperatures were incorporated in a lower bound estimate of increased participation.

As a qualitative assessment, we have assumed that crowding would not have as severe an impact on the study area beaches as in other recreation areas because these beaches are extremely urban and, as one municipal source noted, visitors are used to constant crowding.

Parking facilities close to the beaches could limit visits on a given day as these beaches are used by people throughout the area. Currently, the MDC estimates that on a normal sunny day parking is at 80 percent of capacity although on the hottest days demand for parking greatly exceeds capacity and substantial traffic congestion occurs. Beachgoer preference is to drive to the beach rather than use public transportation which is available and convenient to the cities' beaches. Thus, alternatives to parking do exist if the increased participation should exceed the available parking supply.

With regard to jellyfish, there are practically no data available on this form of life except for some research done in Chesapeake Bay by the University of Maryland's Chesapeake Bay Laboratory. Most of the work has been done in open ocean. Observations in Boston Harbor indicate the presence of a substantial jellyfish population. The fish are present throughout the summer months and, in 1984, have been observed as early as April. The prevalent theory is that polluted water promotes an algae growth within the jellyfish food chain and the population increases in accordance with the food supply. However, scientists caution that there is no evidence to support this theory. Jellyfish are considered to have little food value and consequently have no predators to act as a population control mechanism. Population levels are thought to be decreased by storms, currents and changes in the salinity of the marine environment. The introduction of fresh water into the harbor through CSO's could result in reduced salinity which in turn could promote or deter jellyfish population growth. However, a lack of data makes the issue speculative. An agreed to fact is that the presence of jellyfish in the waters generates an adverse public reaction and acts as a deterrent to water contact activity and, possibly, increased visits to the beaches on days when jellyfish are present. [a]

In attempting to account for the effects of air and water temperature on swimming attendance, for an upper bound estimate the base seasonal attendance figures are limited to the three summer months. For a lower bound estimate the predicted increased attendance is modified according to the distribution of air temperatures during these summer months. [b] On those days with cooler temperatures not all the predicted increased participation due to improved water quality is assumed to take place. Thus, a factor is applied reducing the upper bound estimate in relation to the distribution of air temperature during the summer months (see Appendix B.3).

6.1.2 Recreation Studies

Information on general recreational activities such as percentage of population participating in swimming and percentage of unmet demand for boating and fishing was drawn from a number of existing city, state and federal reports. These include, the New York-New England Recreational Demand Study (Abt, 1979), the 1980 National Survey of Fishing, Hunting and Wildlife

---

[a] Information in this section was provided by EPA, Region I, Boston, MA.

[b] Air temperature is assumed to affect beach attendance. Air and water temperature are assumed to affect the amount of swimming done by those who go to the beach (and are taken into account in estimating swimming health benefits in Chapter 7).

Associated Recreation (US DOI), The 1982-1983 Nationwide Recreation Survey (US DOI), Eastern Massachusetts Metropolitan Area Study (EMMA), (Metcalf & Eddy, 1975), Boston Harbor Islands Comprehensive Plan (Metropolitan Planning Council, 1977), and the Massachusetts SCORP (Massachusetts DEM, 1976). Not all of the information in these studies is specific to Boston Harbor nor does each study supply exactly what is needed for estimating pollution abatement benefits. For example, there is some information about swimming and beach-related activities, but there is very little information available describing fishing and boating activities. In addition, much of the data in these studies are only estimates, rather than statistically-derived results from rigorous sampling, which compromises their use in benefit estimation techniques. We have evaluated a number of these recreation studies for their accuracy, sampling methods and applicabilty to the Boston Harbor case study, and have used only those statistics and numbers which we believe to be representative and unbiased. A brief discussion of each recreational source can be found in Appendix B.7.

6.1.3 Water Quality Data for Logit Model

Water quality data is needed for the application of the travel cost logit model (see Section 6.2.2 below).[a/] There is information about ambient water quality concentrations throughout most of the harbor but it is of limited usefulness due to the shortcomings in sampling procedures (frequency, consistency, regularity, comprehensiveness) and in the comparability of the measurements used to describe water quality. Recently, the MDC has started a water quality sampling program to better identify ambient concentrations of a variety of pollutants such as BOD_5, heavy metals, oil and grease.

[a/] At the time the logit model analysis was run the Boston Harbor Data Management System was not available so that this data had to be collected independently.

Currently, the only readily available water quality data for the MDC and town beaches are measures of fecal and total coliform concentrations. Binkley and Hanemann (1975) collected water quality samples for a number of water quality parameters to be used in their recreational travel cost model, but we have chosen not to use any of their data because water quality samples were only taken once during the summer and thus cannot be considered statistically representative of water quality for the entire swimming season. For this Boston Harbor case study, we collected 1974-1982 fecal and total coliform concentrations and information on beach closings/postings, from the seven MDC beaches and several town beaches in Quincy, Weymouth, Hingham and Hull. In general, the MDC and towns sampled once a week, resampling when high counts were recorded. In cases where only total coliform concentrations were reported, we substituted fecal coliform values based on a statistically significant regression function relating fecal coliform concentrations to total coliform concentrations (see Appendix C). This water quality data, together with data from several other towns in the Boston Metropolitan area, was used in the travel cost logit model.

6.1.4 User (Unit) Day Values

The application of user day values to estimate recreation benefits is the most common and widely used of all the estimation techniques because of its simple methodology and minimal data requirements. Essentially, a single dollar value per recreation day (not per visit) is developed to represent the market value of the recreation services. Originally, this figure per recreation day was based on recreational costs including entrance charges and equipment expenditures. The federal government has adopted a schedule of values to distinguish between "general" and "specialized" recreation activities.[a] A single unit value is assigned per recreation day regardless of whether the user engages in one activity or several. This value should reflect the quality of the activity and the degree to which opportunities to engage in a number of activities are available (Dwyer et al., 1977). We have reviewed a number of user day values for their applicability to Boston Harbor and present the values and their sources in Appendix B, Table B-3.

There are many shortcomings and problems with using user day values to estimate recreation benefits. These limitations are discussed in detail in Dwyer, et al., 1977. The most basic problem is that most user day values--whether based on government or private schedules--may not be developed from empirical data on the actual willingness of participants to pay for recreation. This lack of theoretical or empirical justification for many user day values often leads to arbitrary and biased estimates of the value of a recreation day.

User day values have been developed both nationally and locally. Many of these values tend to be site-specific, reflecting regional socio-economic biases and, more often than not, cannot capture the effects of incremental changes in environmental quality. In addition, user days cannot capture the increased value or utility of the individual recreator. As a result, user day values may produce biased estimates of consumer surplus from improved water quality.

6.1.5 Water Quality Impact

All of the above categories of data are needed to evaluate the response of recreators to water quality changes. The remaining piece of data that is

---

[a] See Federal Register, Vol. 48, No. 48, March 10, 1983.

needed is what the estimated percentage change in water quality will be, given the implementation of a treatment option. Section 4 explained how the percentage reductions in pollution were estimated for the various receptor sites. Table 4-2 and 4-3 presented best-guess ranges and point estimates of the water quality changes. We use these numbers in the benefit calculations.

6.2 Benefits

Reducing pollution in the harbor by upgrading STPs and improving CSOs will lead to recreation benefits throughout the Boston Harbor area. Two major components of consumer surplus should be estimated in order to fully represent all benefits from improved water quality. These components are:

- o increase in participation (both frequency and total numbers)
  - resulting from decreased time and travel costs
  - resulting from a higher quality recreational experience
  - resulting from increase in water areas available for recreation; and
- o increase in the price participants are willing to pay (WTP) for the improved quality of the recreational experience.

A third component can be measured by calculating the value of lost participation due to severe water contamination, such as that resulting from beach closings.

We have used a number of techniques to calculate a range of economic recreation benefits associated with improving water quality in Boston Harbor by upgrading the sewage treatment plants and improving the CSOs. These include:

Benefit	Measure of Consumer Surplus	Benefit Estimation Approach
Swimming	o Increase in participation	o Regional participation o Travel cost (logit model)
	o Increase in WTP per trip	o Travel cost (logit model)
	o Lost participation	o Beach closings

Benefit	Measure of Consumer Surplus	Benefit Estimation Approach
Boating/ Fishing	o Increase in participation	o Regional participation
All Recreation Boston Harbor Islands	o Increase in participation	o Regional participation

Each of these estimation techniques and benefits categories are discussed separately, below. Included in this discussion is a presentation and analysis of the range of benefit values corresponding to the pollution abatement program, limits of the analysis, and pertinent references. A detailed description of the benefit computations and the empirical data is presented in Appendix B.

6.2.1 Swimming--Increase in Participation

One of the significant consumer surplus benefits associated with water pollution abatement in the Boston Harbor study area is the increased use of the beaches by current users and new use by previous non-participants. This is one of the more difficult benefits to measure because of the need for reliable and accurate calculations of user and non-user response. For Boston Harbor, we have assumed that an improvement in water quality--specifically fecal coliform--is equivalent to an increase in total supply of the water resource. Theoretically it is therefore possible to relate this increase in a water resource to a corresponding increase in participation. Increased participation, measured in total visits, should capture both increase in frequency of visits by those already participating, as well as increased new use by previous non-users. Once this population number is calculated, it is possible to value this increased participation by applying user-day values.

Estimating benefits accruing from increase in participation involves the following:

a) determine which areas are affected by each pollution control plan;

b) calculate excess seasonal beach supply;

c) estimate the range of increase in participation using information from regional participation studies;

d) relate the increase in participation to the pollution control plan; then

e) value increased participation by applying a range of user day values.

The first step in estimating the benefits from increased participation involves determining which beaches are affected by the different treatment options. These were determined in Section 4 and presented in Table 4-3. The next step is to calculate the excess supply of each beach, such that increased demand will not exceed the existing supply. This will prevent overstating swimming benefits. Excess seasonal supply of these beaches was estimated using beach attendance data from the MDC and towns, and the capacity of each beach was calculated using a variety of recreational standards and information from town governments and the MDC on acreage and linear feet of shoreline. This data was summarized in Table 6-1. Other factors could serve to limit increased participation, as discussed in Section 6.1.1. However, these effects were not considered here because of insufficient data.

6.2.1.1 Regional Participation Model

The most important step in this methodology involves estimating a range of increased participation. The first approach presented here to estimating increased participation is based on regional and local recreation participation studies. Results of these studies suggest that the number of unmet user days (often called latent demand) in the Boston SMSA is 4.3 to 5.2 million user days. Using this information, we can calculate unmet demand at the beaches that will be supplied by the different pollution control options. These calculations are summarized in Appendix B.1. It is possible to relate this total increase in beach participation to the pollution control plans by assuming that the percentage reduction in pollution will supply a corresponding percentage of the excess supply in terms of additional user days. A number of other assumptions were made in order to calculate increase in participation:

(a) water quality is the major constraint affecting unmet demand;

(b) current facilities are adequate to fulfill the needs of additional visitors;

(c) time available for recreation is not a constraining factor;

(d) fecal coliform is the best <u>available</u> measure of overall water quality affecting participation;

(e) there is little effect of substitution of sites on participation at individual beaches; and

(f) people use the beaches for swimming purposes.

These assumptions and calculations produce the upper bound estimates of increased user days presented in Table 6-2. For the lower bound estimates a factor based on the distribu.ion of air temperatures during the summer months is applied. It is assumed that on days when the air temperature is below 79^{o} Farenheit, not all the predicted increase in beach visits may actually occur even with the improved water quality because of the relatively lower air temperature (see Appendix B.3 for details of the calculations).

Table 6-2. Increased Swimming Participation--Regional Participation Model a/

Beach	CSO	Ocean Outfall	Secondary Treatment	CSO and Ocean Outfall	CSO and Secondary Treatment
			LOWER BOUND ESTIMATES (User Days)		
Constitution	76,099	10,871	5,436	86,970	81,535
Dorchester	157,884	19,736	19,736	177,620	177,620
Wollaston	735,900	91,988	91,988	827,888	827,888
Quincy	42,522	5,315	5,315	47,837	47,837
Weymouth	0	10,619	10,619	10,619	10,619
Hingham	0	2,228	2,228	2,228	2,228
Hull	0	6,623	6,623	6,623	6,623
TOTAL	1,012,485	147,380	141,945	1,159,785	1,154,400
			UPPER BOUND ESTIMATES (User Days)		
Constitution	113,750	16,250	8,125	130,000	121,875
Dorchester	236,000	29,500	29,500	265,500	265,500
Wollaston	1,100,000	137,500	137,500	1,237,500	1,237,500
Quincy	63,560	7,945	7,945	71,505	71,505
Weymouth	0	15,873	15,873	15,873	15,873
Hingham	0	3,330	3,330	3,330	3,330
Hull	0	9,900	9,900	9,900	9,900
TOTAL	1,513,310	220,298	212,173	1,733,608	1,725,483

a/ See Appendix B for details of the calculations.

An alternative approach to estimating increase in participation is to use results from the logit model (described below in Section 6.2.2) which predicts increased visits based on a percent reduction of water pollutants to calculate unmet demand.

It is important to compare the estimates of increased participation due to increases in water quality with the availability of excess supply, in order not to overestimate swimming benefits. We have assumed in the case of the Dorchester/Neponset Bay beaches that if increased participation exceeds capacity at any one beach, then other nearby beaches will serve as substitute sites. This enables us to treat the Dorchester Bay beaches as a unit, rather than individually, and simplifies the analysis.

6.2.1.2 Benefit Estimates

The final step in this methodology is to value the increased participation by applying a range of appropriate user day values, which represent a crude proxy for individual consumer surplus. The results of this valuation are presented in Table 6-3.

Table 6-3. Annual Benefit of Increased Swimming Participation for all Boston Harbor Beaches (1982 $000)

User Day Value	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
$1.60	1,620.0 a/	235.8	227.1	1,855.7	1,847.0
$5.80	7,324.8 b/	1,066.3	1,026.9	8,390.8	8,351.7
$11.06	16,737.2 c/	2,436.5	2,346.6	19,173.7	19,083.8

a/ Lower bound estimate of increased visits (from Table 6-2) multiplied by user day value (from Table B-3, Appendix B).

b/ Average of lower and upper bound estimates of increased visits multiplied by user day value.

c/ Upper bound estimate of increased visits multiplied by user day value.

There is a wide range of estimated benefit values for increased participation because of the many different user day values. Benefits are most substantial for the Dorchester/Neponset Bay Beaches and for the Wollaston and Quincy Beaches. Benefits are more modest for Constitution Beach. Benefits are substantial for Dorchester/Neponset Bay and Wollaston/Quincy beaches because these areas have poor water quality, a large predicted percent cleanup, and a great number of visitors. Thus, cleaning up these areas will attract a large number of new recreators and significantly increase the frequency of participation of current users. Swimming benefits from an increase in participation are small for the STP affected beaches because of the fewer number of people who visit these beaches and because the STP option is expected to abate pollution by only 30 percent.

6.2.1.3 Higher Valued Experience

Improved water quality may also lead to an increase in the price that participants are willing to pay for the improved quality of the recreation experience. This higher valued experience is often very difficult to quantify. Other benefits studies have relied upon surveys of willingness to pay for various improvements in recreational water quality (See for example, Ditton and Goodale, 1972 and Ericson, 1975). Such surveys are often locally biased and, thus, cannot be applied to other areas because of sociological, environmental and economic differences.

No such studies were found to be applicable to Boston Harbor because of the previously mentioned biases. We therefore, were unable to calculate the portion of consumer surplus attributable to a higher valued experience using this method.

6.2.1.4 Limits of Analysis

An analysis of increased participation was limited by both benefit estimation methodology and by data bases. Latent or unmet demand was difficult to measure. Estimates were based on results from regional and local recreational studies, which may be inaccurate for a number of reasons. (For more details see Appendix B.7.) The accuracy of our benefit estimates is greatly influenced by recreation attendance data and capacity estimates. Current attendance figures were based on professional estimates, rather than actual field data, and thus must be considered "best guesses". In addition, these estimates of attendance figures were based on seasonal summer attendance, from Memorial Day to Labor Day, and did not include the number of people who swim before or after the "summer" season. Benefits to these recreators are not captured and, therefore, total benefits may be understated. Beach capacity estimates also represent our best professional judgment. For example, Wollaston has an estimated capacity of 2.75 million people, but the MDC has estimated seasonal attendance to be over 3.5 million. In this case we concluded that the development capacity for Wollaston represents a lower bound and assumed a greater turnover rate than normal and a greater than expected crowding. Other factors, including adequate parking facilities, cold water temperatures and the presence of jellyfish which could limit attendance in a manner similar to beach capacity were not considered because of the lack of data.

These benefit estimates are also limited by the many assumptions which were made, including assumptions about the appropriateness of fecal coliform as the best available water quality indicator, time constraints, and the effect of water quality improvement on increased participation. It was assumed that many relationships were strictly linear, such as the relationship between percentage increase in use and the percentage reduction in water pollution. Such an assumption seems feasible here, since the baseline water quality level is so poor; however, in general, the relationship between percentage reduction in pollution and percentage increase in participation is very sensitive to the baseline water quality level. For example, a 90 percent reduction of pollution in a water body that has relatively good water quality may result in little or no increase in participation. We also assumed that user day values were the best available proxy for consumer surplus. In reality, user day values cannot capture total consumer surplus because they cannot measure increased utility of each visit due to improved water quality. The higher range of user day values ($5.80-$11.06) is, therefore, more appropriate to use than the lower one ($1.60-$5.80) in estimating recreation benefits. All of these limitations, shortcomings and the state-of-the-art nature of benefit estimation will be reflected in the final range of swimming benefits and must be taken into consideration when interpreting the values.

6.2.2 Travel Cost Model--Conditional Logit Analysis

An alternative apporach to estimating increased participation is the logit model which incorporates the probability of visiting a beach as a function of distance to the sites, socioeconomic factors and water quality variables. This approach is a specialization of the so-called travel cost approach first suggested by Harold Hotelling in 1949, then developed by Clawson and Knetsch (1966), and since applied by many others (see Binkley, 1977, for a review of the literature).

6.2.2.1 Methodology

This methodology uses observed recreation travel patterns to infer the recreationists' response to price changes. Travel costs play the role of price in estimating a demand curve for a specific site. Other personal characteristics of the recreationist, such as income and age, are used in the same equation to control for tastes and preferences. Because a demand curve measures the marginal willingness to pay for a good, estimates of recreation benefits can be obtained from the area under a demand curve using travel cost data and information on socioeconomic characteristics. In the present case, we extend this basic methodology to include water quality characteristics in the demand function. Then we can infer the changes in price which would be equivalent to a change in water quality, and from that information can infer the benefit of the change in water quality.

The principal theoretical shortcoming of this approach is the use of travel costs to simulate prices. The recreationist may not respond to prices (i.e., an entry fee) in the same way as he/she does to travel costs because travel may have a special utility or disutility in itself. Part of the disutility of travel might be related to travel time as well as travel costs. (See below for a further discussion of the time issue.) Another common difficulty in the application of the travel cost method is the allocation of joint costs of travel made to several recreation sites as part of a single trip. Because travel costs are used as a proxy for prices, to determine the "price" of an individual site it becomes necessary to separate the cost of travel to one site from that to other sites. Consider, for example, a trip from Boston to the Grand Canyon, then to Yellowstone National Park, and then back to Boston. To infer the recreational value of the Grand

Canyon from this trip, we would need to know what part of the travel costs associated with the whole trip to assign to the visit to the Grand Canyon. The appropriate cost is probably less than the total cost, but could well be more than just the additional cost of including the Grand Canyon in the trip. In short, there is no unambigious way to allocate joint costs of recreation travel. Fortunately, day trips in an urban setting are not likely to be conducted as part of a larger recreational outing, so our analysis probably does not suffer from this limitation.

It is important to discuss the major ways that our methodology differs from the classic implementation of the travel cost approach. First, we consider a system of competing recreation sites. That is, demand for recreation at one site depends on the characteristics of other possible recreation sites that an individual might choose. To our knowledge, aside from the direct antecedents of this work, only three other studies (Cicchetti et. al, 1976; Burt and Brewer, 1971; Morey, 1981) have incorporated this important feature of the problem.

Second, we attempt to explicitly account for travel time as well as travel cost. It is easy to show that ignoring the cost of time spent in recreation leads to biased estimates of the value of a recreation site. This point is well-recognized in the literature (see, for example, Wilman, 1980). The following section on the conditional multinomial logit model acknowledges the empirical difficulties we had in obtaining usable estimates of the value of time and discusses this point further.

Third, we model recreational demand as a discrete choice process. That is, over the summer the individual chooses to go to some sites, perhaps none, but probably not to all the available sites. Consequently there are typically quite a few observations of zero visits, and these observations tell us very little about how he/she trades off water quality with travel distance. Therefore, we would like a model of recreation demand which explicitly accounts for the kind of information contained in this large number of zero observations. The multinominal logit model, borrowed from transportation demand analysis, is one such model. This model was first proposed for recreation demand analysis by Binkley and Hanemann (1975) and subsequently has been developed by Hanemann (1978) and by Feenberg and Mills (1980). Peterson et. al (1983) applied a version of this model to activity choice at the Boundary Waters Canoe area.

The first three studies rely on the same basic data. In 1974, a sample of 500 households representative of the Boston SMSA were interviewed concerning their recreation visits to 29 fresh and saltwater beaches in the Boston area during that summer. A total of 467 usable questionnaires resulted from the survey. Pertinent social and economic data on these families were collected along with information on recreation habits. To compute travel distance and, hence, cost, each of the sample points was located on a map as were each of the recreation sites. In the original three studies, travel distance was computed as the straight line distance between the two points. Also, water quality variables used in the demand equations were derived from one single sample at each beach during July of 1974. (Binkley and Hanemann, 1975, describe the data more fully.)

While sharing a common estimation strategy with these other three studies, the present work employs a somewhat different data base. Recreation patterns and socioeconomic data from the Boston survey were used, but improved information on travel costs and water quality was incorporated. In an urban area, straight line distance is a particularly poor measure of actual travel distance. Fortunately, in the mid-1970's the Central Transportation Planning Staff (CTPS), a regional transportation planning agency for the Boston area, developed a detailed origin-destination travel distance and time matrix for the region. Our sample points and beaches were located in the CTPS transportation zones, and the minimum travel distance and time from each sample point to each beach was computed. Consequently, the measure of distance used in this research reflects much more accurately the actual distance between each individual and the various beaches. In addition, the transportation time information derived from the CTPS study offered the possibility of estimating the value of time in travel for recreation.

Due to large sampling errors, the "old" (Binkley and Hanemann, 1975) measure of water quality--a one time grab sample--might not reflect the true water quality level. We assembled measures of coliform levels from the records of the Metropolitan District Commission and the appropriate towns. These were averaged over the summer, and we employed the median level of fecal coliforms as our "new" measure of water quality. The agencies responsible for some of the beaches did not collect information on fecal coliforms. For these cases, a regression equation was developed relating the old water quality data to the new estimate of fecal coliforms. For the sites where there was no new information, this equation was used to estimate the new data from the old data on fecal coliform (OLD):

$$\underset{(-1.99)}{NEW = -53.27} + \underset{(3.17)}{13.22} \log (OLD) \qquad N = 19, \quad R^2 = 0.371$$

6.2.2.2 The Conditional Multinomial Logit Model

The multinomial logit model of multiple site demand is ideally suited for the situation we consider here: the choice of one or more beaches from a known universe of possible sites.[a/] This section describes the model informally and explains how we obtain estimates of the benefits of water quality improvements from the model. Appendix B.4 presents the model and benefit estimation procedures in more detail.

We want to model the number of visits an individual will make to one or more of the beaches as a function of beach characteristics (including water quality), travel costs/time, and socio-economic characteristics of the individual. With such a model, we can alter the level of water quality at one or more of the sites and simulate how use at all of the sites will change. From those simulated changes in use, we can infer the value of the change in water quality.

The conditional logit model is divided into two parts. The first part describes the probability that an individual will choose to visit each of the beaches given that she/he takes a trip to any of the sites. Equivalently, this part of the model can be thought of as predicting the proportion of all beach visits which will be made to each of the individual beaches. This first part of the model is referred to as the "site choice" model in the following discussions.

The model is called a "conditional" logit model because the choice of sites is conditional on knowing the total number of visits that the individual takes. Hence, the second part of the model explains the total

---

a/ See Domenich and McFadden (1975) for an authoritative treatment of this model.

number of visits an individual makes to <u>any</u> of the study beaches. This second part of the model is referred to as the "visitation" model.

The overall structure of the model can be summarized as follows. The number of visits by individual i to beach j is n_{ij}. The individual makes a total of n_i beach visits during the summer. The probability of an individual i going to beach j (or the proportion of her/his total beach visits which are made to beach j) is p_{ij}. Then we model the number of visits to beach j by individual i as:

$$n_{ij} = n_i p_{ij} \qquad (6.1)$$

We estimate n_i in the visitation model and p_{ij} in the site choice model and predict n_{ij} using this equation.

For the site choice model, the dependent variable is the probability of visiting a given beach. While this variable is precisely the probability of visiting a certain beach, it can also be considered the proportion of the time that an individual will go to a particular beach when she/he goes to the beach at all. The probability of visiting a certain beach (given that a trip is taken) is assumed to be a function of the desirability of that beach. We take desirability to depend on the characteristics of the beach (e.g., water quality), the travel cost/time associated with a visit to that beach, and the socioeconomic characteristics of the invididual who is making the trip. Through the procedures described in Appendix B, the probability of visiting a beach is estimated as a linear function of these variables. The results for the site choice model which are presented below can be interpreted much as one would interpret an ordinary linear regression.

The dependent variable for the visitation model is the number of visits an individual made to any of the study area beaches during the summer. We assume that the total number of beach visits an individual takes is related to the socioeconomic characteristic of the individual and the overall desirability of the sites available to her/him. While there are many ways this latter variable might be measured, the details of constructing the conditional logit model require that it be derived from the site choice model in a specific way. This variable, called the "inclusive price", measures the average desirability of the available sites. Here, the term desirability has the same meaning as it did in the description of the site choice model and includes the level of water quality at each of the beaches. Through the inclusive price term in the visitation model, a change in water quality at one or more beaches will not only affect the split of visits among the various beaches, but will also affect the total number of beach visits which will be taken.

Linking together the site choice model, the visitation model, and Equation 6.1 permits one to model how changes in water quality at any of the sites will affect total number of visits to each of the sites. To simulate the effect of a change in water quality at one or more of the sites, we use the visitation model to predict total number of visits after the change in water quality, the site choice model to predict the fraction of the visits which will be made to each site, and Equation 6.1 to determine the number of visits made to each site.

In general, the benefits associated with a simulated improvement in water quality come from two sources: an increase in the total number of visits and an increase in the value of each of the visits. Of course, because the demand model includes the interaction among beaches, a water quality improvement at one beach might lead to a decrease in use at some other beach. All of these shifts in usage are included in our benefits calculations.

Conceptually, we are interested in determining the equivalent variation. Suppose we improve water quality at some set of beaches. The equivalent variation is the amount of income we would have to take away from an individual to make her/him indifferent between the situation with higher income/lower water quality and that with lower income/higher water quality. The equivalent variation measures this willingness of an individual to pay for an improvement in water quality. This measure of benefit is a good approximation to other measures of benefit (Willig, 1976 and 1978) and also is of interest in its own right.

Because income is not explicitly incorporated in the demand model, the equivalent variation cannot be estimated directly. We use a modification of a procedure developed by Small and Rosen (1982) and adapted to this problem by Feenberg and Mills (1980) to determine the equivalent variation associated with a change in water quality. The details of the procedure are presented in Appendix B.4, but the method can be outlined as follows. Demand is a function of travel distance and water quality. In the estimated demand model, then, we know how an individual trades off travel distance and water quality. We can estimate the value of a simulated improvement in water quality by asking how much further could the individual travel given the water quality improvement and be no worse off than she/he was before the water quality improvement took place. Benefits are measured in units of distance. Therefore, in order to put benefits in dollar units, we need to know the cost per unit distance.

Here we take cost to have two components: a money cost and a time cost. It is important to discuss how time should enter the model. Because time is a scarce resource which the recreationist must allocate, the amount of time spent in travel and on the site itself should be included in the model. Failure to do so will lead to an underestimate of the value of the site. Unfortunately, the data available for this study does not permit usable estimates of the effect of these two time variables. The survey data on time spent on the site contained numerous missing observations. Further, it is not conceptually clear how to measure the amount of time which would be spent on sites not visited. Thought of in another way, we need to estimate a three part model--site choice, visitation and time spent on site--and the data are not adequate to do so. Attempts to include travel time along with distance in the model failed because of the high collinearity between the two variables.

An alternative procedure was employed to partially account for the value of time. Cesario (1976) suggested that the value of travel time for recreation is about one third the wage rate. Consequently, our estimates of welfare change were converted to money values of the basis of $0.12/mile (the national average in 1974) plus travel time valued at one-third the individual's wage rate.

The wage rate was computed from information on income and the number of days worked per year. From the household survey, we know the number of days taken off per week, the number of holidays per year and the annual amount of vacation time. By subtracting the sum of these figures from 365 days, we know the number of days worked per year. Annual income is divided by the number of working days to determine the average daily wage. Daily wage is converted to an hourly wage assuming eight hours per work day.

6.2.2.3 Model Results

The recreation demand analysis provides several kinds of results. First, we present the estimates of the site choice and visitation models. These results are compared with those of Feenberg and Mills (1980) to show the effect of our different and, in our view, better measures of travel costs and water quality. Second, we use the procedures, outlined above and detailed in Appendix B.4, to simulate the effect of changes in water quality on recreation patterns and to estimate the recreation benefits of several specific water quality improvement scenarios for the Boston Harbor study area. These results depict total benefit curves for each of the water quality improvement scenarios.

Table 6-4 presents the estimates of the model parameters. The model, using all 467 cases, predicts the site choice correctly in 15.9 percent of the cases compared with 34.7 percent for the Feenberg-Mills model. We attribute this difference primarily to the fact that Feenberg and Mills grouped individuals according to residential (origin) location, which we did not. In addition, our specification of the site choice model omits several interaction terms (age x distance, income x distance). We felt that there was no good a priori rationale for including these interaction terms. The dis'ance coefficient for the Feenberg-Mills model is about 0.33 expressed in one-way miles and evaluated at the mean of the interaction terms. This is more than three times higher than the value we obtained indicating the magnitude of the error from using straight line distance to proxy for actual travel distance in an urban area.

There are several other interesting differences in the two models which can be seen in the simulation results. A 10 percent reduction in coliform

Table 6-4. Conditional Logit Model Estimates

Site Choice:	coefficient	t
Distance (miles one way)	-0.1003	-50.71
Water Temperature (°F)	-0.4088	-41.17
Fresh water (dummy)	-1.607	-27.79
Fecal Coliform (median)	-0.01275	-18.47
	At Convergence	At Zero
log likelihood (x10^5)	-0.1443	-0.1658
percent correctly predicted	15.9	3.5
Visitation	coefficient	t
Intercept	172.7	--
Inclusive Price	5.757	3.26
Age (years)	-0.3095	4.12
Education (years)	-0.5758	1.68
Income ($1974 x 10^3)	0.2550	2.31
	R^2 = 0.078	
	f (4,462) = 9.79	

Note: Parameter estimates for the site choice model were obtained using QUAIL Version 3.5.

Source: Model developed and run by Clark Binkley, Yale University, School of Forestry and Environmental Sciences.

levels can be accompanied by an increase in two way travel distance of 0.254 miles and leave the individual's utility level unchanged. In the Feenberg-Mills model evaluated at the mean value of all the interaction terms, a 10 percent reduction in all water quality variables (total bacteria, oil, color) offsets an 0.5 mile increase in travel distance. It is curious that we find a negative value for the fresh water dummy variable, indicating Bostonians prefer salt water to fresh water beaches, where Feenberg and Mills report a positive value. In sum, our model, using better travel cost and water quality data for a larger sample of individuals, seems to be more sensitive to water quality and less sensitive to distance than is the Feenberg-Mills model.

6.2.2.4 Benefit Estimates

The model presented above can be used to obtain estimates of the benefits of water quality improvement. Recall that the benefit measure we use is the equivalent variation measured in units of distance. These units are converted to units of dollars at the rate of $0.12/mile for travel costs plus an amount which reflects the time cost of travel: travel time valued at one-third the individual's wage rate. Travel time was determined from the CTPS study mentioned above. The wage rate was computed from information on income and the number of days worked per year as was described above. These per mile figures were doubled to reflect the fact that the demand model was estimated on one-way rather than two-way distance.

Four sets of simulations were performed. In each case the fecal coliform level at a single beach or group of beaches in the Boston Harbor Study area was decreased in increments of 10 percent up to a 90 percent improvement in water quality. These simulations map out the total benefit curve for water pollution abatement in the various segments of Boston Harbor. Sites 7 (Constitution Beach) and 15 (Wollaston Beach) were examined separately because of their importance to Boston Harbor-based recreation and because of their location within the harbor. Sites 8 - 14, the beaches in the Dorchester/Neponset Bay CSO planning areas, (south from Castle Island to Tenean Beach), were treated as a group in a third simulation. Finally, a simulation including all of the sites 7 - 15 was performed, with 10 percent less water quality improvement at site 7 than the others. This simulation shows the effect of a full water pollution abatement program for the Boston Harbor Study area.

The summary results from these simulations are given in Table 6-5. The entries in the table are benefits per person per year and the corresponding change in visits per person for a given pollution reduction. Thus, to get a value per visitor day for the site the per capita benefit is divided by the change in per capita visits. The value per visitor day for the different sites and pollution reduction levels ranges from $5.60 to $5.70 (in 1974 dollars) and is within the range of user-day values found in the literature (see Table B-3, Appendix B). Total benefits rise steadily with increasing levels of water quality improvement, and the curve continues to climb even as high levels of abatement are achieved. This results in a marginal benefit curve which curves upward rather than downward as is commonly assumed. This unusual result might stem from the fact that the demand model was estimated using data from beaches generally having water quality levels much less than the 80 to 90 percent levels imply.

Table 6-6 summarizes the change in per capita visits for each of the control options. Then, the increases in number of visits are derived by multiplying change in per capita visits by the 1980 Census Boston

Table 6-5. Per Capita Annual Benefit Estimates from Conditional Logit Model a/ ($1974/capita/year)

	SITES			
	7 Constitution	8-14 Dorchester	15 Wollaston	7-15 b/ All
Value per visitor day c/	5.62	5.62	5.69	5.65
Equivalent 1982 dollars	11.00	11.00	11.14	11.06
% Reduction in Water Pollution				
10	.0340 (.006054)	.1562 (.02779)	.1176 (.02069)	.2731 (.04835)
20	.0687 (.01222)	.3240 (.05765)	.2469 (.0434)	.6014 (.1065)
30	.1040 (.01851)	.5055 (.08995)	.3889 (.06837)	.9539 (.1689)
40	.1400 (.02491)	.7030 (.1251)	.5446 (.09575)	1.334 (.2361)
50	.1766 (.03143)	.9192 (.1636)	.7155 (.1258)	1.744 (.3087)
60	.2140 (.03807)	1.158 (.2060)	.9027 (.1587)	2.189 (.3874)
70	.2521 (.04481)	1.422 (.2530)	1.108 (.1947)	2.672 (.4729)
80	.2908 (.05174)	1.718 (.3056)	1.332 (.2342)	3.199 (.5661)
90	-- --	2.050 (.3646)	1.577 (.2773)	3.774 (.6680)

a/ Change in per capita visits for given change in pollution is in parentheses.

b/ Reduction at site 7 is 10 percent less than reduction at site 8-15 (i.e., the first entry is a 10 percent reduction at 8-15 and no reduction at 7).

c/ Calculated by dividing $/capita/year by change in per capita visits and averaged over all percent pollution reduction simulations.

Note: For location of sites see map (Figure 6-1).

Table 6-6. Increased Participation Estimates from Conditional Logit Model

Site No.	Beach	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
				Percent Pollution Abatement a/		
7	Constitution	70	10	5	80	75
8-14	Dorchester/ Neponset	80	10	10	90	90
15	Wollaston	80	10	10	90	90
7-15	All Sites	70/80	10	5/10	80/90	75/90
				Increase in Per Capita Visits b/		
7	Constitution	.0448	.0061	.003	.0517	.048
8-14	Dorchester/ Neponset	.3056	.0278	.0278	.3646	.3646
15	Wollaston	.2342	.0207	.0207	.2773	.2773
7-15	All Sites	.5661	.0484	.0484	.6680	.6171
				Lower Bound Increase in Number of Visits c/		
7	Constitution	82,821	11,277	5,546	95,577	88,737
8-14	Dorchester/ Neponset	564,958	51,393	51,393	674,031	674,031
15	Wollaston	432,962	38,267	38,267	512,641	512,641
7-15	All Sites	1,046,541	89,477	89,477	1,234,922	1,140,824
				Upper Bound Increase in Number of Visits d/		
7	Constitution	123,798	16,856	8,290	142,866	132,641
8-14	Dorchester/ Neponset	844,482	76,821	76,821	1,007,520	1,007,520
15	Wollaston	647,178	57,201	57,201	766,279	766,279
7-15	All Sites	1,564,336	133,747	133,747	1,845,922	1,705,268

a/ From Table 4-3.

b/ Based on Table 6-5.

c/ Derived by multiplying per capita increase by entire 1980 Boston SMSA population of 2,763,357 by reduction factor in Appendix B.3.

d/ Derived by multiplying per capita increase by entire 1980 Boston SMSA population of 2,763,357.

SMSA population. The value of increased visits can be calculated by multiplying increased visits by the consumer surplus per visit. These are presented in Table 6-7. Not surprisingly, these annual benefits are high. This is the result of both the large number of beach users and the large estimated percentage reduction in pollution.

6.2.2.5 Limits of Analysis

The principle theoretical shortcoming of this conditional logit approach is the link between objective water quality parameters and the subjective perception by recreationists of water quality. Some water quality parameters (e.g., dissolved oxygen) are not easily perceived by recreationists and, consequently, an improvement in water quality (i.e., an increase in DO levels in the water) may not be perceived by recreationists, and their behavior (i.e., frequency of visits to the site) may not change.

This is not likely to be the case for the beaches in the Boston Harbor study area. Dornbusch's study (1975) found that floating debris and oil and grease were the most frequently perceived water quality indicators applicable to the logit, travel cost model as applied here. The presence of high fecal coliform counts, the water quality parameter used in this study, is highly correlated to oil and grease measures (Hanemann, 1978), parameters which are perceived by recreationists. Thus, the concern that recreation behavior is governed by perception and, ideally, the predicted changes in behavior be linked to water quality parameters that are perceived by recreationists has been addressed in this application of the logit model by using fecal coliform, instead of dissolved oxygen, as the water quality variable.

Table 6-7. Annual Benefit Estimates from Conditional Logit Model (1982 $000)

Site No.	Beach	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
			LOWER BOUND ESTIMATES			
7	Constitution	911.0	124.0	61.0	1,051.3	976.1
8-14	Dorchester/ Neponset	6,214.5	565.3	565.3	7,414.3	7,414.3
15	Wollaston	4,823.2	426.3	426.3	5,710.8	5,710.8
7-15	All Sites	11,574.7	989.6	989.6	13,658.2	12,617.5
			UPPER BOUND ESTIMATES			
7	Constitution	1,361.8	185.4	91.2	1,571.2	1,459.1
8-14	Dorchester/ Neponset	9,289.3	845.0	845.0	11,082.7	11,082.7
15	Wollaston	7,209.6	637.2	637.2	8,536.3	8,536.3
7-15	All Sites	17,301.6	1,479.2	1,479.2	20,451.9	18,860.3

Source: Derived by multiplying $1982 value per visitor day from Table 6-6 by increase in number of visits.

An additional shortcoming of this conditional logit approach is the use of travel costs to simulate prices. Travel costs may be difficult to specify because travel may have a special utility or disutility in itself, based on aesthetics of the travel route and travel time, in addition to travel costs. The improved water quality data, the incorporation of travel time, and the estimation of travel distance, and the estimation of consumer surplus, however, make the logit model the most empirically and theoretically sound of all the methodologies used to estimate swimming benefits from improving water quality in Boston Harbor.

Despite these limitations, the benefit estimates resulting from the logit model are instructive in two ways. The difference in the estimates of increase in demand as measured by user days using the logit technique (Table 6-6) as opposed to the increased participation technique (Table 6-2) depend on the treatment option and the beach location. The logit model predicts greater participation for the STP options (ocean outfall and secondary treatment) and less participation under the CSO and CSO and STP combined options than does the increased participation approach. For the individual beaches the logit model predicts greater participation at Dorchester/Neponset and Constitution while less participation at Wollaston. The predicted increased days for the logit model are within the bounds of seasonal capacity as estimated above (see Section 6.1.1). The other factors, such as crowding, adequate parking and presence of jellyfish, however, have unknown impacts as was noted above for the increased participation approach. In addition, the average value per visitor day determined by the logit model--$11.06--is almost twice as great as the moderate user day value of $5.80, indicating that applying a user-day value of that magnitude to estimate consumer surplus may seriously understate total benefits.

6.2.3 Swimming--Beach Closings

An alternative method for calculating swimming benefits from increased participation because of improved water quality is to determine the value of lost participation if beaches are closed because of fecal contamination. Essentially, this technique estimates the dollar value of the number of daily beach closings by multiplying the average consumer surplus per daytrip (in dollars per unit) by the daily attendance at each beach and by the number of daily beach closings due to water pollution.

The information needed to calculate these benefits using this technique is usually more readily available than detailed information required for benefit estimation using the previously described increased participaton technique, and thus this method has often formed the basis for calculating total swimming benefits. In the case of Boston Harbor beaches, different health standards are applied according to beach ownership. The MDC does not actually close beaches when fecal coliform measures are high enough to represent a health hazard, but they do post signs that the beaches are unsafe for swimming. Signs are posted at an MDC beach when fecal coliform counts exceed 500 MPN/100 ml. A few towns use a standard of 1,000 MPN/100 ml total coliform. Federal standards are the most strict, suggesting closure when fecal coliform counts exceed 200 MPN/100 ml.

The first step in this technique is to decide which health standard to apply. We have chosen to use the strict federal standard of 200 MPN/100 ml to establish an upper bound and the MDC standard of 500 MPN/100 ml as a lower bound. We did not choose the 1,000 MPN/100 ml as a lower bound because few of the affected town beaches use this level, and there are few times during the season when coliform concentrations reach this high a level. We have also assumed that there is limited or no attendance at the beaches during the days when fecal coliform counts exceed the 200 MPN/100 ml and 500 MPN/100 ml levels.

The next step is to relate bacteriological contamination with daily attendance figures so that we can arrive at a number of lost recreation days. Unfortunately, as previously described, the only attendance figures available are seasonal (Memorial Day to Labor Day) data, making it difficult to assess the exact number of swimmers affected by daily beach closings. There is also the added complication that weekend attendance at beaches is usually greater than weekday attendance and, therefore, weekend violations of water quality standards have a greater impact on potential losses than weekday violations. Data limitations prevented us from considering this effect. Instead we have assumed a direct proportional relationship between total seasonal attendance figures and percentage of times during the season that water quality levels exceed 200 MPN/100 ml and 500 MPN/100 ml. For example, if a beach has water quality levels which exceed 200 MPN/100 ml during five percent of the season, then we assume that five percent of total attendance will be affected and will not go to the beach (see Appendix B.5 for details). This assumption probably understates the case since water quality problems tend to be the worst during the hottest times of the year, when beach attendance is the highest.

6.2.3.1 Boston Harbor Beaches

In order to arrive at savings according to the CSO and STP options, it is necessary to multiply these base visits by the predicted percent cleanup. These base-case lost visits and their corresponding averted lost visits due to pollution control programs are presented at the top of Tables 6-8 and 6-9. The final step in this methodology is to value these averted lost attendance days by applying a range of user-day dollar values. These values represent the savings due to averted beach closings due to pollution abatement in Boston Harbor and are presented at the bottom of Tables 6-8 and 6-9.

6.2.3.2 Nantasket Beach

The only other swimming beach in our study area is Nantasket Beach. It is expected to be adversely affected by the deep ocean outfall option (see Table 4-3). We have used only the beach closing method to estimate the effects on swimming at Nantasket Beach because of the limitations of available data and methodology for measuring effects of increases in pollutant levels.

Seasonal population at Nantasket Beach is estimated to be 3,035,000, based on information from Binkley and Hanemann (1975) and the MDC. Currently, Nantasket Beach has water quality levels which exceed 200 MPN/100 ml approximately 2.3 percent of the season. Water quality is expected to decrease by 10 percent from current levels if a deep ocean outfall is constructed. It is difficult to predict the relationship between this percentage decrease in water quality and the corresponding percentage changes in pollutant concentrations exceeding 200 MPN/100 ml and 500 MPN/100 ml. We have chosen to conservatively assume that the water quality level at Nantasket will exceed 500 MPN/100 ml at least as frequently as it was exceeded at the 200 MPN/100 ml level, or 2.3 percent of the season. By multiplying the seasonal attendance estimates by this percentage, we arrive at a number of lost visits totalling 69,805. These lost visits can be valued by applying a range of user day values from $1.60 to $11.06. Thus, we arrive

Table 6-8. Annual Benefit of Averted Beach Closings at 200 MPN/100ml (1982 $000)

Beach	Number of Lost Visits a/	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
		Averted Lost Visits b/				
Constitution	29,019	20,313	2,902	1,451	23,215	21,764
Dorchester						
Castle Island	1,010	808	101	101	909	909
Pleasure Bay	11,779	9,423	1,178	1,178	10,601	10,601
Carson	6,604	5,283	660	660	5,943	5,943
Malibu	14,423	11,539	1,442	1,442	12,981	12,981
Tenean	41,519	33,215	4,152	4,152	37,367	37,367
Wollaston	518,870	415,096	51,887	51,887	466,983	466,983
Quincy	13,687	10,950	1,369	1,369	12,319	12,319
Weymouth	11,966	-	3,590	3,590	3,590	3,590
Hingham	-	-	-	-	-	-
Hull	3,505	-	1,052	1,052	1,052	1,052
TOTAL	652,382	506,627	68,333	66,882	574,960	573,50[illegible]
User Day Value		Annual Benefit of Averted Beach Closings c/ for All Boston Harbor Beaches (1982 $000)				
$ 1.60		810.6	109.3	107.0	876.7	860.0
$ 5.80		2,938.4	396.3	387.9	3,178.2	3,117.5
$11.06		5,603.3	755.7	739.7	6,060.4	5,994.8

a/ See Appendix B.5.

b/ Number of lost visits multiplied by percent pollution abatement (in Table 4-3).

c/ Total averted lost visits multiplied by user day value (in Table B-3, Appendix B).

Table 6-9. Annual Benefit of Averted Beach Closings at 500 MPN/100ml (1982 $000)

Beach	Number of Lost Visits a/	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
		Averted Lost Visits b/				
Constitution	11,606	8,124	1,161	580	9,285	8,704
Dorchester						
Castle Island	433	346	43	43	389	389
Pleasure Bay	5,049	4,039	505	505	4,544	4,544
Carson	4,714	3,771	471	471	4,242	4,242
Malibu	4,328	3,462	433	433	3,895	3,895
Tenean	24,107	19,286	2,411	2,411	21,697	21,697
Wollaston	259,435	207,548	25,944	25,944	233,492	233,492
Quincy	6,537	5,230	654	654	5,884	5,844
Weymouth	-	-	-	-	-	-
Hingham	-	-	-	-	-	-
Hull	3,505	-	1,052	1,052	1,052	1,052
TOTAL	319,714	251,806	32,674	32,093	284,480	283,899
User Day Value		Annual Benefit of Averted Beach Closings c/ for All Boston Harbor Beaches (1982 $000)				
$ 1.60		402.9	52.3	51.3	455.2	454.2
$ 5.80		1,460.5	189.5	186.1	1,650.0	1,646.6
$11.06		2,785.0	361.4	354.9	3,146.3	3,139.9

a/ See Appendix B.5.
b/ Number of lost visits multiplied by percent pollution abatement (in Table 4-3).
c/ Total averted lost visits multiplied by user day value (in Table B-3, Appendix B).

at a range of $111,688 to $772,043, which represents a conservative estimate of swimming-related pollution costs at Nantasket Beach attributable to implementation of the deep ocean outfall option.

6.2.3.3 Benefit Estimates

It is clear that the greatest benefits will derive from cleaning up the Dorchester Bay and Wollaston Beaches because these are the areas with the greatest and most frequent water quality violations, and they are the most popular beaches. Tenean and Wollaston Beaches, especially, have the greatest number of averted lost visits. Based on the strict 200 MPN/100 ml standard, Wollaston has nearly 520,000 lost visits while Tenean has over 41,500.

Benefits to the STP-affected beaches of Weymouth, Hingham and Hull are extremely low for both the upper bound and lower bound case for a number of reasons. These include the fairly good quality of shoreline water, the fact that the STP pollution control programs are expected to reduce fecal coliform concentration and, thus, reduce beach closings, by only 30 percent, and the fact that attendance is low at these beaches.

6.2.3.4 Limits of Analysis

These dollar benefits are significantly lower than the values calculated for swimming benefits using the increased participation methodology, previously described. The reasons for this difference are many and only serve to emphasize the many limitations and shortcomings of using this methodology to estimate recreation benefits. Normally, beach closings are calculated by relating the intensity of rain events to CSO overflow and the corresponding effect on ambient water quality and beach attendance. This methodology was not utilized, however, because of data limitations and because a substantial portion of ambient water quality problems in beach areas in Boston Harbor stems from problems with dry weather overflow (DWO). The beach closing methodology attempts to capture the general seasonal relationship between CSO/DWO events and beach participation based on seasonal averages of ambient water quality and estimates of seasonal beach attendance. It underestimates total swimming benefits because it cannot capture the dollar value of increased number of visits due to cleaner and more attractive beaches, nor can it capture the increase in willingness to pay for safer and cleaner bathing areas. In addition, these estimates for Boston Harbor are based on the assumption that there is a direct correlation between percent fecal contamination and percent beach closings. In reality, this relationship may not be directly proportional and, in fact, there may not be a significant relationship between the two parameters. We can only conclude that this methodology seriously underestimates swimming-related benefits, and that this range of values is a less appropriate measure of water pollution abatement benefits than values derived from previously described techniques.

6.3 Recreational Boating

One of the significant consumer surplus benefits associated with water pollution abatement in Boston Harbor is the increased use and utility of harbor waters by boaters, and the savings in dollars spent on these activities. Unfortunately, unlike the previously described swimming-related benefits, there is little available information upon which to base these benefits. Instead, we make only very general estimates of consumer surplus using a number of assumptions about increased participation and the corresponding value of these increases and applying aggregated information from regional and federal recreation studies.

6.3.1 Increased Participation

It has been well documented that improved water quality can have an important effect on the level of recreational boating (Davidson, Adams and Seneca, 1966). Participation in all boating activities in Boston Harbor--sailing, motor boating, canoeing and windsurfing--is expected to increase with corresponding decreases in water pollutant levels. Benefits from this improvement stem from an increase in frequency of participation by previous users, willingness to pay a higher price for the boating experience because of improved water quality, and new participation by previous non-users. Much of this increased participation is likely to come from increases in the aesthetic boating experience due to the decreased offensiveness of presently polluted areas, especially those areas directly surrounding the sewage treatment plants and near CSO outfalls. Improvements to CSOs in Dorchester Bay and the Deer and Nut Island STPs will most definitely improve water quality and, thereby, encourage increased recreational boating in these areas. Unfortunately, there are few boating participation studies which link a change in water quality to a change in boater use of water resources which are applicable to Boston Harbor and, thus, recreation participation data on present use, along with data on unmet demand, was used to estimate boating benefits from improvements in water quality.

We have used a benefit estimation methodology which is similar to the increased participation technique described for swimming related benefits. Using data from a variety of recreational sources we have estimated the number of user days per year for two categories of boating--motor boating and sailing. Although there are no quantitative measures of predicted percentage increases in boating that are expected to occur under the various CSO and STP options, we can estimate this increased participation by assuming that cleaner waters will supply a portion of unmet (latent) demand. Two of the recreational studies have estimated a 45-69 percent unmet demand in the Boston Metropolitan area for boating. This translates into a need of 1.8 to 2.8 million days for motor boating and 0.8 to 1.3 million days for sailing. We can assume that some of this demand will be met by cleaning up harbor waters, although it is not immediately clear what percentage will actually be met. Because fishing and boating take place throughout the harbor and are not restricted to certain areas we have calculated these benefits on a harbor-wide basis for the two combined options, CSO plus Ocean Outfall and CSO plus Secondary Treatment. We have assumed that abating pollution from CSO and Ocean Outfall controls will lead to a 2 to 10 percent reduction in unmet demand. We assumed the CSO plus Secondary Treatment option would meet 5 to 12 percent of unmet demand. The lower figures for the deep ocean outfall option reflect the adverse impact this option is expected to have on the area around the Brewsters Islands.

Although these figures might appear to be overly conservative, we have chosen them for two reasons. First, we believe that the latent demand of 45-69 percent reported in the recreational studies is probably an overestimate (and have chosen to use 50% in our calculations). Second, even though more boaters might increase their use of Boston Harbor when pollution is decreased, there is a limited supply of available marinas, boatyards and docks. Thus, for every ten new boaters who might want to use the harbor, only one might actually be able to because of limited facilities. In other words, we have assumed that the binding constraint on increases in boating participation is not only poor water quality, but the supply of boating facilities as well. This has been demonstrated by Davidson et al. (1966) who determined that the supply of boatable water is affected by the depth, width, access, and quality of a water resource. In this study the upper bound benefit estimate is determined by the facility availability constraint.

6.3.2 Benefits Estimates

Using these assumed recreational figures, it is possible to calculate the number of increased boating days. By applying a lower bound user day value of $18.14 and an upper bound value of $45.19 (see Table B-3, Appendix B) to the range of increased boating days, we arrive at the estimated value of benefits for boating activities (see Table 6-10).

6.3.3 Limits of Analysis

Calculation of boating-related benefits is limited by both methodology and data base. Statistics on use and participation were inconsistent among all sources, requiring us to judge which statistics were the most appropriate for a given step in the estimation process. There was scant information on latent demand, requiring us to use a possibly overstated estimate from a Boston-based study. Benefit estimation was further compromised by having to assume what percentage of latent demand was met by cleaning up harbor waters, a prediction based on professional judgment rather than quantitative information. All of these shortcomings are reflected in the final benefit values. In addition, this benefit methodology does not capture total consumer surplus in that only the benefits of water quality improvement to new participants, and not increased utility and increased participation of

Table 6-10. Annual Saltwater Boating Benefits
(1982 $)

	Motor Boating	Sailing	Total
LATENT DEMAND			
% of SMSA	22	15	
# of recreators	607,938	414,504	1,022,442
User Days per Participant	6.7	4.5	
# of User Days	4,073,185	1,865,268	5,938,453
Latent Demand (50%)	2,036,593	932,634	2,969,226
LOWER BOUND ESTIMATES			
% Latent Demand met by			
CSOs and Ocean Outfall	2	2	2
CSOs and Secondary Treatment	5	5	5
Days of Latent Demand met by			
CSOs and Ocean Outfall	40,732	18,653	59,385
CSOs and Secondary Treatment	101,830	46,632	148,462
Annual Benefits (User Day Value = $18.14[a])			
CSOs and Ocean Outfall	3,694,000	1,692,000	5,386,000
CSOs and Secondary Treatment	4,433,000	2,030,000	6,463,000
UPPER BOUND ESTIMATES			
% Latent Demand met by			
CSOs and Ocean Outfall	10	10	10
CSOs and Secondary Treatment	12	12	12
Days of Latent Demand met by			
CSOs and Ocean Outfall	203,659	93,263	296,922
CSOs and Secondary	244,391	111,916	356,307
Annual Benefits (User Day Value = $40.89[a])			
CSOs and Ocean Outfall	8,328,000	3,814,000	12,129,000
CSOs and Secondary Treatment	9,993,000	4,576,000	14,569,000

[a] See Table B-3, Appendix B.

previous users, is measured. These benefit values also understate total boating-related benefits because other boating activities, such as canoeing and windsurfing, have not been considered and because reductions in the amount of fouling of boats and equipment have not been considered. Finally, although boating benefits are substantial when estimated for the entire study area in the Boston Harbor, data limitations prevented disaggregating these benefits to the level of the areas specifically affected by the pollution abatement options. Thus, these benefit estimates can only be used to emphasize the relative importance of the effect of improved water quality on recreational boating and to underscore the conclusion that these effects are both monetizable and significant.

6.4 Recreational Fishing

The benefits to recreational fishing of improving water quality in Boston Harbor has two components. First, cleaner water will affect the availability of fish, both species and numbers. Second, this change in fish availability will affect fishing participation rates. In addition, there may be a "perception" effect on fishing activity which is independent of this availability, implying a more positive response towards fishing in cleaner water.[a] The consumer surplus from improving water quality should, thus, be measured by calculating increases in participation stemming from changes in fish species and numbers and the increased utility or willingness to pay a higher price to fish in cleaner water.

---

[a] An informal survey by Metcalf and Eddy (1982) reported that, although in general it did not appear that fishers avoided discharge areas, one bait shop owner had reported that the Nut Island discharge made the area unattractive for his clients. In another, larger, survey conducted by the Massachusetts Division of Marine Fisheries (1982), concern was expressed over the effects of pollution by toxic chemicals and sewage waste (65-60 percent felt these were serious problems), loss of fish habitat (57 percent), adequate stocks of fish to catch (43 percent).

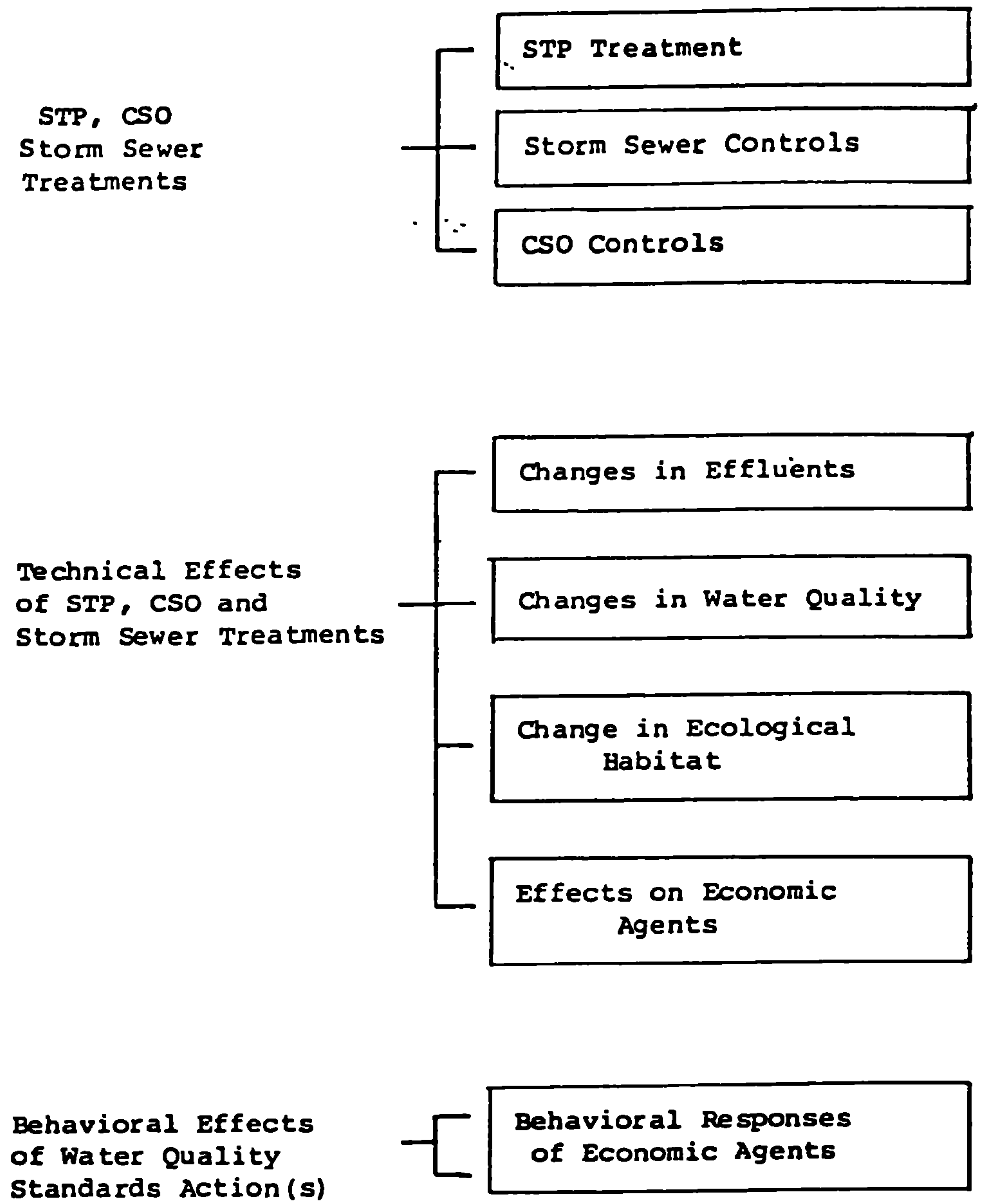
6.4.1 Components of Recreational Fishing

Calculating this fishing-related consumer surplus is difficult however, because it involves assessing the technical effects/impacts of the pollution control actions, including changes in ecological habitat, as well as determining the behavioral effect of these actions. These steps are summarized in Figure 6-2.

A number of studies have attempted to model and analyze the effects and responses of fish and anglers to changes in water quality from pollution control programs. Bell and Canterbery (1976) modeled biological production functions of important recreational fish and applied them to recreational fisheries data to arrive at estimates of recreational fishing benefits for each state in the Union. We have chosen not to apply their results to the study area because of methodological and data limitations. One other study (Russell and Vaughan, 1982) developed a model to estimate the probability of being an angler, the probability of spending time to fish, and the average length of time for each type of fishing. Their model estimates the effects of water quality changes on number of fishing sites, types of supportable fish population, and change in aesthetic experience. This model can only be used for freshwater fishing areas and, thus, cannot be applied to the Boston Harbor Study area.

It was not possible to calculate many of the effects and responses listed in Figure 6-2, which is a prerequisite to calculating measures of consumer surplus. It was particularly difficult to determine how pollution control plan effluents would precisely affect or change the ecological habitats of important recreational fish. The preferred summer recreational fish in the harbor is winter flounder (*Pseudopleuronectes americanus*) although other

Figure 6-2. Effects and Responses to STP, CSO and Sewer Controls



desirable species include striped bass (Morone saxatilis), bluefish (Pomatomus saltatrix), and cod (Gadus morhua). Winter flounder appears to be the only species definitely affected by Harbor pollution, preferring the more organically polluted areas to the cleaner ones. Despite this attraction to polluted areas it was not possible to link these changes with the specific pollution control options. In general, productivity throughout the Boston Harbor Study area is expected to increase with corresponding decreases in water pollutants, although we were not able to quantitatively determine the increase in productivity. These data limitations required us to apply a general participation approach to estimate fishing benefits, similar to the method previously described under boating benefits.

Recreation studies provided information on percentage participation, value of user days, and total user days per year for marine fishing. We were unable to find direct, reliable figures on latent demand and, thus, we assumed a rate identical to that used for boating. We applied a user day value of from $12.90 to $28.46 per user-day derived from a number of studies presented in Table B-3, Appendix B. The results are presented in Table 6-11.

6.4.2 Benefits Estimates

Fishing benefits can only be estimated for the entire Boston Harbor Study area, rather than for each distinct geographical area. The possibility of double counting some boaters who primarily fish from their boats exists. However, no information was available to suggest how prevalent this kind of behavior might be. For this reason, these benefit figures should be interpreted with caution.

Table 6-11. Annual Recreational Fishing Benefits
(1982 $)

	Lower Bound	Upper Bound
Latent Demand		
% of SMSA	7	14
# of recreators	193,435	386,810
User Days per Participant	12	12
# of User Days	2,321,220	4,642,440
Latent Demand (50%)	1,160,610	2,321,220
% of Latent Demand met by		
CSOs and Ocean Outfall	2	10
CSOs and Secondary Treatment	5	12
Days of Latent Demand met by		
CSOs and Ocean Outfall	23,212	232,122
CSOs and Secondary Treatment	58,030	278,546
User Day Value [a]	$12.89	$34.08
Annual Benefit Value		
CSOs and Ocean Outfall	299,000	7,911,000
CSOs and Secondary Treatment	749,000	9,493,000

[a] See Table B-3, Appendix B

6.4.3 Limits of Analysis

Estimation of recreational fishing benefits is limited by methodology and data base in ways similar to those described under boating benefits. A major limitation of this analysis is the lack of information linking changes in water quality to corresponding changes in both biological habit and fish population. This lack of data prevented a precise estimation of the effects of availability and number of fish species on fishing participation. Another problem was that the available recreation fishing statistics on participation and unmet demand were often inconsistent, requiring us to judge which were the most appropriate for a given step in the estimation process. Another limitation of the analysis is that the methodology used here does not capture all components of consumer surplus. Benefit values reflect only benefits to new participants, and not the value of increased utility or increase in participation by previous users. The last limitation of this analysis is the possibility of some double counting of fishing and boating benefits. Thus, these estimates can only be used to emphasize the importance of the effect of improved water quality on recreational fishing.

6.5 Boston Harbor Islands

The Boston Harbor Islands are a unique natural resource in a metropolitan area which possesses only half of the recommended minimum acreage of open space per thousand population. The Islands are predominantly open, natural areas which offer a wide range of activities such as swimming, boating, fishing, hiking, picknicking, camping and historic sight-seeing. Most of the islands have limited recreational facilities, which restrict current and potential visits. However, effluent from the two sewage treatment plants seriously degrades water quality around the islands, also discouraging recreation. Assuming that the planned recreational facilites were constructed, then improving water quality around the islands would lead to a corresponding increase in both frequency of participation and total number of visitors. It is possible to roughly estimate this increased participation, despite scarce recreational data.

6.5.1 Increased Participation

Recreational data from the Boston Harbor Islands Comprehensive Plan, (Metropolitan Planning Council, 1972) suggests that current attendance at all the Islands for all recreational activities is 265,000 per season and that total capacity, assuming the planned structural improvements and additions are implemented, is 560,000 per season. This results in an excess supply of 295,000 visits per season. Given the unique nature of the Harbor Islands, we have assumed that some of the latent demand for recreation in the harbor--especially swimming, boating and fishing--could be met largely by improving water quality around the Islands. Implementation of either of the STP options is expected to improve the water quality around the nearest Harbor Islands. However, implementation of the deep ocean outfall option is expected to have adverse effects on the Brewsters Islands, which are the outermost islands of Boston Harbor. The Brewsters include Great Brewster, Middle Brewster, Outer Brewster, Calf, Little Calf and Green Islands, Shag Rocks, and the Graves. These islands constitute one of the most unique marine environments on the Massachusetts coast, providing a highly accessible marine habitat, conservation areas, and excellent sites for recreational diving. Water quality is expected to decrease by 10 to 15 percent in the area surrounding these islands because they are so close to the ocean outfall diffuser. Consequently, many of the recreational activities such as diving, swimming, boating and hiking will be affected by this degradation of water quality.

To develop benefit estimates for recreational activities at the Harbor Islands we have assumed a percentage increase (decrease) in visits and applied a range of previously utilized user day values. The assumptions and calculations of these benefit values are presented in Table 6-12.

6.5.2 Limits of Analysis

The previously described methodology is limited by both its data bases and its assumptions. There is little available information on latent demand for the Boston Harbor Islands and, thus, we had to assume an upper and lower bound participation rate. Although there are accurate estimates for current Harbor Island attendance, capacity estimates should be interpreted and used with caution. The derived benefit estimates probably underestimate STP-related benefits for the Islands because the applied methodology cannot, theoretically, capture either the dollar value of increased utility or the value of increases in frequency of participation. These benefit values should also be viewed as rough estimates because of the possibility of double-counting from other benefit categories such as boating and fishing for the entire harbor and because costs of upgrading recreational facilities, which are a necesary prerequisite to increased participation, have not been included.

6.6 Summary of Recreation Benefits

Reducing water pollution in the Boston Harbor Study area by implementing the different pollution control options will result in many recreation

Table 6-12. Annual Benefits for Recreation on Boston Harbor Islands

(1982 $000)

	Outer Harbor Islands	Brewsters Islands
Current Attendance	258,000	7,000
Capacity	546,000	14,000
Excess Supply (latent demand)	288,000	7,000
% Change in Water Quality		
Ocean Outfall Option	60 to 90	-10 to -15
Secondary Treatment Option	30 to 80	30 to 40
% of Latent Demand met by		
Ocean Outfall Option	50 to 90	-20 to -30
Secondary Treatment Option	50 to 75	50 to 75
Change in Visitor Days due to a/		
Ocean Outfall Option	144,000 to 259,200	-1,400 to -2,100
Secondary Treatment Option	144,000 to 216,000	3,500 to 5,250
User Day Values b/	$5.80 to $11.06	$5.80 to $11.06
Annual Benefit Values (1982 $000)		
Ocean Outfall Option	835 to 2,867	-8.1 to -23.2
Secondary Treatment Option	835 to 2,389	20.3 to 58.1

a/ Change in Visitor Days calculated by multiplying latent demand by the percentage of latent demand met by the different treatment options.

b/ See Table B-3, Appendix B.

benefits (see Table 6-13). A variety of methodologies have been used to calculate the range of these benefits. These include: (1) swimming--increased participation; (2) swimming--travel cost with conditional logit model; (3) swimming--beach closings; (4) boating and fishing--increased participation; (5) all recreation activities for Boston Harbor Islands--increased participation.

Recreation benefits as calculated by the travel cost method, are greatest in the category of swimming. Benefits associated with the CSO options are substantial while STP-related swimming benefits are minor, because the majority of swimming in the harbor study area takes place along shorelines, which are not as adversely affected by STPs. Fishing and boating benefits have been calculated only for the entire harbor and not for each treatment alternative, because of data limitations. Benefits for both these categories are also substantial while the greatest STP-related recreation benefits are from water quality improvements near the Boston Harbor Islands.

Table 6-13. Annual Recreation Benefits
(Thousands of 1982$)

Benefit	CSO	Ocean Outfall	Secondary Treatment	CSO plus Ocean Outfall	CSO plus Secondary Treatment
A. SWIMMING					
1. Increased participation					
a. Recreation studies a/					
High:	16,737	2,436	2,347	19,174	19,084
Low:	1,620	236	227	1,856	1,847
Moderate:	7,325	1,066	1,027	8,391	8,352
2. Increased Participation and Increased Utility of Visit					
a. Logit model: b/					
High:	17,302	1,479	1,479	20,416	18,860
Low:	11,575	990	990	13,658	12,618
Moderate:	14,439	1,235	1,235	17,037	15,739
3. Beach Closings					
a. Strict c/ 200 MPN f.c.					
High:	5,603	756	740	6,060	5,945
Low:	811	109	107	877	860
Moderate:	2,938	396	388	3,178	3,118
b. Lenient d/ 500 MPN f.c.					
High:	2,785	351	355	3,146	3,140
Low:	403	52	51	455	454
Moderate:	1,461	189	186	1,650	1,647
c. Nantasket Beach e/					
High:	0	(772)	0	(772)	0
Low:	0	(112)	0	(112)	0
Moderate:	0	(405)	0	(405)	0
B. BOATING f/					
Increased Participation					
High:	NA	NA	NA	12,129	14,569
Low:	NA	NA	NA	5,386	6,463
Moderate:	NA	NA	NA	8,758	10,516
C. FISHING g/					
Increased Participation					
High:	NA	NA	NA	7,911	9,493
Low:	NA	NA	NA	299	749
Moderate:	NA	NA	NA	4,105	5,121
D. BOSTON HARBOR ISLANDS					
Increased Participation h/					
High:	0	2,844	2,447	2,844	2,447
Low:	0	827	855	827	855
Moderate:	0	1,835	1,651	1,835	1,651

a/ From Table 6-3.
b/ From Table 6-7, does not include. Quincy town beaches.
c/ From Table 6-8.
e/ From Section 6.2.3.2; costs not benefits.
f/ From Table 6-10.
g/ From Table 6-11.

References

Abt Associates, 1979. New York-New England Recreational Demand Study, Vol. I and II, Cambridge, MA

Bell, F.W. and E.R. Canterbery (1975). An Assessment of the Economic Benefits Which Will Accrue to Commercial and Recreational Fisheries from Incremental Improvements in the Quality of Coastal Waters, Florida State University, Tallahassee, FL.

Ben-Akiva, J., 1973. The Structure of Passenger Travel Demand. MIT PhD. dissertation, Department of Civil Engineering.

Binkley, Clark S. and W. Michael Hanemann, 1975. The Recreation Benefits of Water Quality Improvement. U.S. Environmental Protection Agency, Washington, DC, NTIS PB257719.

Binkley, Clark S., 1977. Estimating Recreation Benefits: Critical Review and Bibliography. CPL Exchange Bibliography 1219.

Burt, Oscar R. and David Brewer, 1971. Estimation of net social benefits from outdoor recreation. Econometrica. pp 613-827 in Abel, Tihansky and Walsh, 1976, National Benefits of Water Pollution Control, Draft U.S. EPA Office of Research and Development, Washington, DC.

Cesario, F. J., 1976. The Value of Time in Recreation Benefit Studies. Land Economics, 52: 32-41.

Charbonneau, J. and J. Hay, 1978. "Determinants and Economic Values of Hunting and Fishing." Paper presented at the 43rd North American Wildlife and Natural Resource Conference. Phoenix, Arizona.

Cicchetti, C., A. Fisher and V. K. Smith, 1976. An Econometric Evaluation of a Generalized Consumer's Surplus Measure: the Mineral King Controversy. Econometrica, 44: 1253-1276.

Clawson, M. and J. H. Knetsch, 1966. The Economics of Outdoor Recreation. Johns Hopkins University Press: Baltimore.

Davidson, P., G. Adams and J. Seneca, 1966. The social value of water recreational facilities from an improvement in water quality: The Delaware Estuary, Water Research, Allen Kneese and Stephen C. Smith, eds., Baltimore: Johns Hopkins University Press for Resources for the Future, 1966.

Development Planning and Research Associates, Inc., 1976. National Benefits of Achieving the 1977, 1983 and 1985 Water Quality Goals, U.S. EPA, Office of Research and Development, Washington, DC.

Dornbusch, David M., 1975. The Impact of Water Quality Improvements on Residential Property Prices, National Commission on Water Quality, Washington, DC.

References

Ditton, R. and T. Goodale, 1972. Marine Recreation Uses of Green Bay: A Study of Human Behavior and Attitude Patterns, Technical Report No. 17, Sea Grant Program, University of Wisconsin, Madison.

Domenich, T. and Daniel McFadden, 1975. Urban Travel Demand. North Holland, Amsterdam.

Dwyer, John, John R. Kelly and Michael D. Bowes, 1977. Improved Procedures for Valuation of the Contribution of Recreation to National Economic Development. University of Illinois, Water Resources Center, Urbana, IL.

Ericson, Raymond, 1975. Valuation of Water Quality in Outdoor Recreation, PhD. Dissertation, Department of Economics, Colorado State University, Fort Collins, CO.

Feenberg, Daniel and Edwin Mills, 1980. Measuring the Benefits of Water Pollution Abatement, Academic Press, New York, NY.

Federal Register, Vol. 48, No. 48, March 10, 1983.

Hanemann, W. M., 1978. A Methodological and Empirical Study of the Recreation Benefits from Water Quality Improvement. PhD dissertation, Harvard University, Cambridge, MA

Heintz, H.T., A. Hershaft, and G.C. Horak, 1976. National Damage of Air and Water Pollution, U.S. Environmental Agency, Office of Research and Development, Washington, DC.

Massachusetts Department of Environmental Management, December, 1976. Massachusetts Outdoors: Statewide Comprehensive Outdoor Recreation Plan (SCORP), Boston, MA.

Massachusetts Division of Marine Fisheries, 1982. Massachusetts Marine Fisheries Management Report, Boston, MA.

McFadden, D., 1973. Conditional Choice Logit Analysis of Qualitative Choice Behavior in P. Zarembka, ed. Frontiers in Econometrics, Academic Press, New York.

Metcalf and Eddy, 1975. Eastern Massaschusetts Metropolitan Area Study (EMMA). Technical Data (Volume 13B), Socio-Economic Impact Analysis, Boston, MA.

Metcalf and Eddy, Inc., 1982. Application for Modification of Secondary Treatment Requirements for its Deer Island and Nut Island Effluent Discharges into Marine Waters, for Metropolitan District Commission, Boston, MA.

Metropolitan Planning Council, October 1972. Boston Harbor Islands Comprehensive Plan, for Massachusetts Department of Natural Resources, Boston, MA.

References

Morey, E.R., 1981. The Demand for Site-Specific Recreational Activities: A Characteristics Approach. J. Env. Econ. and Management, 8:345-371.

National Planning Association (NPA), 1975. Water-Related Recreation Benefits Resulting from Public Law 92-500. National Commission on Water Quality, Washington, DC.

Peterson, G., D. H. Anderson and D. W. Lime, 1983. Multiple-Use Site Demand Analysis: An Application to the Boundary Waters Canoe Area. J. Liesure Res. 14: 27-36.

Russell, C.S., and W.T. Vaughan, 1982. The national fishing benefits of water pollution control, Journal of Environmental Economics and Management, 9:328-353.

Small, K. and H. Rosen, 1981. Applied Welfare Economics with Discrete Choice Models. Econometrica 40: 105-130.

U.S. Department of Commerce, Bureau of the Census, 1982. 1980 Census of Population and Housing, Massachusetts. Washington, DC.

U.S. Department of Interior, March 1970. Outdoor Recreation Space Standards, Washington, DC.

U.S. Department of the Interior, 1982. 1980 Survey of Fishing, Hunting, and Wildlife Associated Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

U.S. Department of the Interior, April 1984. The 1982-1983 Nationwide Recreation Survey, National Park Service, Washington, DC.

Willig, R., 1976. Consumer's Surplus without Apology. AER 66: 589-597.

Willig, R., 1978. Incremental Consumer's Surplus and Hedonic Price Adjustment. J. Econ. Theory 17:227-253.

Wilman, E., 1980. The Value of Time in Recreation Benefit Studies. J. Env. Econ. and Management 7: 272-286.

Section 7
Health Benefits

In order to assess the health benefits of reducing the level of pollution in Boston Harbor, it is first necessary to understand the adverse effects that such a level of pollution might have on users of Boston Harbor waters. Until recently, most health effects associated with water have been estimated for withdrawal uses for drinking water supplies rather than for instream uses, such as swimming, or other withdrawal uses, such as fish consumption. This focus, in part, has been due to what the public views as the more serious nature of ingesting sewage contaminated water, but it has also been affected by the relative ease of determining causal relationships between water ingestion and illness as opposed to water contact and illness or the less direct link of water pollutants to the food chain. Attempts to quantify morbidity values and the corresponding benefits of decreasing the incidence of illnesses contracted while swimming in polluted waters or consumption of contaminated food have been made difficult by the lack of data on dose-response and the corresponding population at risk.

This section focuses on two types of health benefits: swimming-related illness and illness related to bacterial contamination of shellfish. Other health risks, such as those due to the accumulation in the food chain of heavy metals and toxics (e.g., copper, mercury, PCBs and silver found in the tissues of lobsters and winter flounder), cannot be estimated because little is known about how the accumulation takes place, the effects of consumption or the dose response. Consequently, the benefits described in this section must be viewed as a partial analysis of the possible health benefits of improving water quality in the Boston Harbor.

7.1 Swimming-related Health Benefits

The method used to estimate swimming-related health benefits defines the population at risk and then applies a dose-response relationship. A discussion of the dose-response relationship used in this analysis is included below because this approach is a fairly recent development.

7.1.1 Benefit Measurement Approach

One of the dose-response data problems for water contact and disease is related to the indicators used to predict and quantify illness in the population. The conventional wisdom regarding public health and water borne disease assumes that since sewage contains fecal material and fecal material may contain pathogens, then the level of fecal material is an adequate measure of the potential for pathogens in the water. The parameter most commonly used as an indicator of the potential for pathogens is the fecal coliform bacterial count in the water column. Fecal coliforms are, in fact, an excellent indicator of the presence of domestic sewage, but they do not supply the kind of information needed to develop a dose-response relationship for swimming-related illnesses.

Recently, it has been established that the presence of another bacterial indicator, *Enterococci*, is a more accurate measure of water quality than fecal coliforms (Cabelli *et al.*, 1980, 1982; Meiscier *et al.*, 1982). This is principally due to the fact that *Enterococci* better mimic the aquatic behavior of the viruses responsible for the potentially most serious (infectious hepatitis) and common (gastroenteritis) water-related enteric diseases. In his 1980 and 1982 articles, Cabelli developed a dose-response relationship between Enterococci density and the number of cases of gastrointestinal symptoms per 1000 swimmers.

In order to apply this dose-response data to Boston Harbor beaches it was necessary to perform some preliminary calculations and transformations of the water quality data. All of the water quality data for Boston area beaches is recorded in terms of concentrations of fecal and total coliforms, as required by local, state and federal health standards, rather than in concentrations of Enterococci. Using Enterococci data gathered from local Boston beaches we developed a statistical relationship between the more available indicator, fecal coliform, and the more accurate indicator, Enterococci. (See Appendix C for more details.)

Given the correspondence between fecal coliform and Enterococci and the dose-response relationship between Enterococci and gastrointestinal symptoms, it was possible to correlate water quality at affected beaches with potential swimming-related illness. Water quality data from 1974-1982 were collected and averaged for all Boston area beaches and a percentage range of fecal coliform concentrations was established. As described under the swimming/ beach closings section, population at risk was calculated by assuming proportional relationships between seasonal attendance figures and percent of time during the season that water quality levels fell into various ranges. For example, if fecal coliform standards fell between 30 and 50 MPN/100ml for two percent of the entire season at a beach, we assumed that two percent of the seasonal swimming population would be affected by this level of fecal coliform. In addition, we assumed that there were no swimmers among the visitors on days when fecal coliform counts were above 500 MPN/100 ml since this is the standard most of the towns and municipalities use for closing beaches or posting them as unsafe for swimming.

Given these different water quality levels and number of bathers at risk, we estimated the number of potential cases of gastrointestinal illness. These are presented in Table 7-1. (See Appendix C for details of the calculation.) For a lower bound estimate of number of cases of illness, population at risk can be changed to reflect visitors to the beach who actually go swimming. If not all visitors to a beach go swimming, then not all visitors would be exposed to water pollution. The lower bound estimates of numbers of cases of illness reflect an estimate of 49% of all beach visitors actually go swimming. In addition, even with the improved water quality not all of the predicted increased visitors may go swimming because of air and water temperatures. During the 1982 and 1983 summer season, for example, over half of the days had water temperature below 65° F or air temperature below 75° F. For such days, some beach visitors may not go swimming. To take into account these relatively colder temperatures in the Boston Harbor area a factor based on the distribution of air and water temperatures is applied to reduce population at risk and, thus, the number of cases of illness. (See Appendix C.3 for derivation of population at-risk.)

The final stage in estimating swimming-related health benefits was to value these illnesses. Based on information from Cabelli et al. (1980), we have assumed that each case lasts from one to two days and requires sick leave from work but does not require medical treatment. We have applied a

Table 7-1. Annual Reduction in Cases of Gastrointestinal Illnesses

Beach	CSO Option	Ocean Outfall Option	Secondary Treatment Option	CSO Plus Ocean Outfall Option	CSO Plus Secondary Treatment Option
Constitution	161-596	21-79	11-39	248-919	200-741
Dorchester Bay					
Castle Island	21-77	2-7	2-7	28-103	28-103
Pleasure Bay	242-896	21-79	21-79	325-1203	325-1203
Carson	134-497	12-45	12-45	182-675	182-675
Malibu	198-735	18-68	18-68	285-1056	285-1056
Tenean	65-239	15-57	15-57	175-647	175-647
Wollaston	2419-8961	293-1085	293-1085	4144-15348	4144-15348
Quincy	238-881	19-70	19-70	344-1275	344-1275
Weymouth	0	45-168	45-168	45-168	45-168
Hingham	0	9-35	9-35	9-35	9-35
Hull	0	27-100	27-100	27-100	27-100
Nantasket	0	(352)-(1302)*	0	(352)-(1302)*	0
Total	3478-12882	133-491	473-1753	5461-20227	5765-21351

* Increased cases of illness

See Appendix C for details of the calculations.

full wage rate of $8.10/hour for two days to arrive at an upper bound value of $129.56 per case and one-half the wage rate of $8.10/hour for one day to arrive at a lower bound value of $32.40 per case (1982$). These results are presented in Table 7-2. Since the cost of illness is not the same as the willingness to pay to avoid illness, these lost earnings represent a conservative proxy for the value of good health. Other factors might include a value for discomfort avoided and expenditures on medical care.

7.1.2 Benefit Estimates

The health benefits that are derived from cleaning up harbor waters are substantial for some parts of the Boston Harbor Study area and insignificant for others. The Wollaston and Quincy beaches show the greatest benefit because of the great number of beach visitors, the poor level of water quality, and the large percentage of predicted cleanup. Benefits for the Constitution and Dorchester Bay Beaches are not as great because, although water quality is often poor at the beaches, the water is not consistently dirty and, therefore, the greater number of cases of swimming-related gastroenteritis occur only sporadically. The benefits at Weymouth, Hingham, and Hull beaches are low because the water is relatively clean during most of the season, percent predicted cleanup is only 30 percent, and attendance figures are low compared to other Boston Harbor beaches.

7.1.3 Limits of Analysis

The key difficulties in accurately calculating health benefits are the water quality and population-at-risk data limitations, as well as the problems associated with valuing morbidity. Although we were able to develop

Table 7-2. Swimming Health Benefits[a]
(1982 $000)

	CSO Option[b]	Ocean Outfall Option	Secondary Treatment Option	CSO Plus Ocean Outfall Option	CSO Plus Secondary Treatment Option
	$32.40-$129.56	$32.40-$129.56	$32.40-$129.56	$32.40-$129.56	$32.40-$129.56
Constitution	5.2-77.2	0.7-10.2	0.3-5.1	8.0-119.1	6.5-96.0
Dorchester Bay	21.3-316.7	2.3-33.1	2.3-33.1	32.2-477.3	32.2-477.3
Castle Island	0.7-10.0	0.1-0.9	0.1-0.9	0.9-13.3	0.9-13.3
Pleasure Bay	7.8-116.1	0.7-10.2	0.7-10.2	10.5-155.9	10.5-155.9
Carson	4.3-64.4	0.4-5.8	0.4-5.8	5.9-87.5	5.9-87.5
Malibu	6.4-95.2	0.6-8.8	0.6-8.8	9.2-136.8	9.2-136.8
Tenean	2.1-31.0	0.5-7.4	0.5-7.4	5.7-83.8	5.7-83.8
Wollaston	78.4-1161.0	9.5-140.6	9.5-140.6	134.3-1988.5	134.3-1988.5
Quincy	7.7-114.1	0.6-9.1	0.6-9.1	11.2-165.2	11.2-165.2
mouth	0	1.5-21.8	1.5-21.8	1.5-21.8	1.5-21.8
Hingham	0	0.3-4.5	0.3-4.5	0.3-4.5	0.3-4.5
Hull	0	0.9-13.0	0.9-13.0	0.9-13.0	0.9-13.0
Nantasket[c]	0	(11.3)-(168.7)	0	(11.3)-(168.7)	0
TOTAL	112.7-1,669.0	4.3-63.6	15.3-227.2	176.9-2,620.7	186.8-2,766.3

[a] Value per case of illness times number of cases from Table 7-1.

[b] $32.40 represents one day lost work at one-half wage rate and $129.56 represents two days lost work at full wage rate.

[c] Increased costs rather than savings.

a good statistical relationship between fecal coliform and Enterococci because of available Boston data, in general such relationships are difficult if not impossible to determine because of variability in water quality conditions, which affect the survival patterns and relationships between various bacterial indicators in marine waters. Benefit estimates are also subject to bias because of assumptions made about water quality levels and swimming participation, because attendance figures only measure seasonal, and not yearly, beach visits because beach attendance may not reflect actual time spent in the water, and because the costs of illness do not include any measure of medical treatment.

In addition, estimating health benefits from swimming may be subject to double counting since swimmers may perceive most of the health effects associated with water pollution. These benefits would thus be captured in whole or in part by the logit estimation, described in the previous Section of this report. More important than these limitations, however, is the fact that previously unavailable dose-response information can now be used to predict the number of swimming-related illnesses, provided towns and cities measure the appropriate indicator of bacterial contamination.

A note of caution is warranted in using the Cabelli et al. dose response function. This study is based on limited testing and the results have not been duplicated or verified by other studies.

7.2 Shellfish Consumption

Theoretically, health benefits resulting from improved water quality can be estimated by relating the reduction in frequency of water-related diseases to the reduced contamination of shellfish attributed to various levels of pollution abatement. Quantifying these benefits is difficult because of the unavailability of a dose-response function for shellfish-borne diseases such as gastroenteritis, infectious hepatitis, and salmonellosis. Additional difficulties are caused by the lack of information on the magnitude of shellfish contamination and corresponding estimates of the population at risk. Benefit estimation is further complicated by the difficulty in valuing morbidity effects. Despite these methodological shortcomings, it is important to attempt to estimate some of the shellfish-related benefits, if only to illustrate that such techniques can be applied, given appropriate data.

It is possible to calculate benefits from reduction in incidence of disease by applying assumed, rather than scientifically-derived, relationships between water quality levels and incidence of disease. Assuming that disease rates are proportional to the level of contamination, it is possible to calculate a percentage reduction in the number of shellfish-borne cases of disease based on a corresponding percentage cleanup. Almost one-half of the shellfish acreage in Boston Harbor is classified as "grossly" contaminated and is closed to harvesting because of potential health threats. It has been estimated that, despite this closure, hundreds of bushels of contaminated clams are being illegally harvested ("bootlegged") from these closed beds, and sold on the open market. It is difficult to estimate the number of contaminated clams that are reaching consumer tables, and even more difficult to estimate what proportion of these clams can be linked to occurrence of diseases. The only available indicator of shellfish-related diseases are the actual reported outbreaks of gastroenteritis, hepatitis and other diseases.

In Boston, there have been few reported outbreaks of gastroenteritis or other shellfish-related diseases. The Commonwealth of Massachusetts recorded one outbreak of 30 cases of shellfish-related gastroenteritis in 1980. This low disease rate does not necessarily indicate that there is little risk of contracting shellfish-borne diseases or that shellfish contamination, due to polluted waters, does not exist. Rather, it suggests that a high proportion of cases are unreported, especially for the more common gastroenteritis cases. One study (Singley, et al., 1975) suggested that the ratio of actual to reported cases of foodborne diseases is 12:1. If this ratio were applied to the data from Boston, then we would expect a minimum of 360 cases per year of gastroenteritis due to shellfish contamination. Assuming a similar scenario as described under swimming effects, these cases could be valued at a low of $32.40 and a high of $129.56. Potential damages would then range from $11,664 to $46,642.

It is not possible to relate reduction in water pollution, resulting from implementation of different pollution control plans, to corresponding reductions in incidence rate of these diseases and corresponding reductions in morbidity values because of the inadequate information relating a specific case to a specific shellfish area. It is important to note, however, that provided adequate data, the above technique can be applied, and corresponding benefits can be valued.

References

Cabelli, Victor J., et al., 1980. Health Effects Quality Criteria for Marine Recreational Waters, Environmental Protection Agency, EPA-600/1-80-031.

Cabelli, V.J., A.P. Dufour, L.J. McCabe, and M.A. Levin. 1982. Swimming Associated Gastroenteritis and Water Quality. American Journal of Epidemiology, 115:606-616.

Meiscier, John J. and Victor J. Cabelli, 1982. Enterococci and Other Microbial Indicators in Municipal Wastewater Effluents, Journal of the Water Pollution Control Federation, Vol. 54, No. 12.

Singley, J. Edward et al., 1975, A Benefit/Cost Evaluation of Drinking Water Hygiene Programs, U.S. Environmental Protection Agency.

Section 8

Commercial Fisheries Benefits

Commercial fishing within Boston Harbor and the perimeter of Massachusetts Bay includes shellfishing, lobstering and finfishing. It is difficult to predict the precise impact of the various pollution abatement options because of lack of data on both productivity changes in relation to pollutant levels and current yields from the study area, especially for lobstering and finfishing. Because of differences in the available data, this section presents a general view of the potential impacts on lobsters and finfish and more detailed calculations for shellfishing.

As will be seen, the near-term benefits from reducing water pollution are modest. The most important factor affecting this lack of improvement is the problem of sediment contamination, which is affected by all sources of pollution (STPs, CSOs, non-point runoff, unauthorized site dumping, illegal discharges, and town sewers). The sediment throughout Boston Harbor is a sink for a number of toxic pollutants, particularly for heavy metals such as mercury, copper, nickel and silver, for PCBs, and for a number of pesticides, all of which are potentially detrimental to fish productivity and consumer health. There is scarce information about the precise levels of these contaminants in the sediment and even less information about their turnover and flushing rates. Added to this dilemma of ediment contamination is the problem of bacterial pollution from illegal dischargers, non-point sources and town sewers, all of which are difficult to locate, making it nearly impossible to precisely define their corresponding receptors. For these reasons, we have had to apply quite restrictive assumptions to the benefit calculations.

8.1 Lobstering and Finfishing

Lobstering is the most valuable fishery conducted within Massachusetts state waters. Total 1981 lobster landings were 9.5 million pounds and, at a value of $2.09 per pound, were worth $19.8 million.[a/] Most of the lobstering activity occurs in Essex and Plymouth counties, along shoreline areas. Prior to 1979, the Massachusetts Division of Marine Fisheries did not keep data in a form which made it possible to determine amounts which were harvested in any particular area of the Harbor. Metcalf & Eddy (1982) have estimated that Dorchester Bay is the most productive area of the Harbor, followed in productivity by Quincy and Hingham Bays.[b/] In 1979, however, the Division expanded the boundaries of the statistical catch area for lobster to include the entire Boston Harbor and portions of Massachusetts Bay out to a depth of 120 feet. Within this area, stretching from Lynn to Scituate and east past the Brewsters Islands, the total 1981 lobster catch was 2.6 million pound worth $5.4 million if valued at $2.09 per pound, accounting for about 27 percent of total Massachusetts lobster supply.

Finfishing is also a commercial activity in Boston Harbor and the immediate Massachusetts Bay area. Boston is one of 51 commercial fishing harbors in Massachusetts, and in 1979 ranked third in Massachusetts in pounds of finfish landed. The approximately 57 gilt net line trawl vessels operating in and around the Harbor fish primarily for winter flounder, cod, and pollock, mostly during the summer months. There are also 29 draggers registered in Boston of which a small percentage fish within the Harbor area for menhaden and, just outside Boston Harbor, for winter flounder, yellow tail flounder, and cod. In addition, there are four seine boats which are known to fish the

---

a/ Massachusetts Division of Marine Fisheries estimates.

b/ Lobster harvest was approximately 140,000 kg (308,000 lbs.) in Dorchester Bay in 1967 and 80,000 kg (176,000 lbs.) in Hingham Bay in 1970.

waters at the perimeter of Boston Harbor and Massachusetts Bay for sea herring. The National Marine Fisheries service records finfish landings in Boston Harbor but, unfortunately, these records do not include where the fish species are caught. For the year 1981, 28.4 million pounds of fish were landed in the port of Boston for a value of $12.4 million (National Marine Fisheries Service, 1983).

It is expected that reducing pollutant levels from the CSOs and the STPs will increase the productivity of lobstering and finfishing within the study areas but it is not possible to say by how much. On the other hand one treatment alternative, the deep ocean outfall option, will increase pollutant levels immediately surrounding the ocean diffuser in Masschusetts Bay. This option is expected to have an adverse impact on lobstering and finfishing activities in that area.

It is difficult to predict the precise impact that effluent from the ocean outfall discharge--which includes BOD, suspended solids, heavy metals and toxic chemicals--will have on the productivity of lobstering and finfishing because of insufficient dose-response data at sublethal concentrations and because of deficiencies in current knowledge of variations in ambient concentrations of water pollutants, which vary according to depth, current patterns, temperature conditions, tidal influences and estuarine influences. We must assume that pollution from ocean outfall effluent will have similar environmental effects as those reported for Boston Harbor, despite their biological, chemical and physical differences. Some information does exist, however, which enables us to predict the range of transport of some of the pollutants and the corresponding qualitative predicted impact of discharge on benthic fauna and commercial fisheries productivity.

Circulation in Massachusetts Bay (location of the ocean outfall) is not as efficient in terms of dispersion as are other area coastal locations, because the Bay is partially enclosed. Circulation is further restricted because of the depressed topographic features. The predicted ocean outfall discharge of 494,200 lbs/day of BOD and 369,000 lbs/day of suspended solids (including associated toxic pollutants such as PCBs, pesticides, and heavy metals) is expected to have an adverse effect on the biological population within the immediate discharge area and beyond the zone of initial dilution, although exact quantification of these effects is currently not possible. The discharge from the ocean diffuser is not expected to violate the Massachusetts' dissolved oxygen standard at the boundary of initial dilution, but it could be expected to violate the far-field and steady state benthic oxygen demand criteria due to abrupt resuspension.[a/]

As stated in the waiver denial (US EPA, 1983) the proposed deep ocean outfall is expected to contribute nutrient stimulation of phytoplankton resulting in an adverse increase of pollution-tolerant phytoplankton and an increase in the amount of phytoplankton propagated at the existing site.[b/] No measurable effects are expected for zooplankton-populations. The dilution dynamics at the proposed discharge site, the differences in the community structure of some of the populations, and the numerous near-shore pollution sources make it difficult to predict precisely the nature of the impact on biological community dynamics. In general, the proposed discharge is predicted to result in moderate, and possibly major, adverse impacts on the benthos. Major benthic alterations resulting from a sedimentation rate of 486 $g/m^2/yr$ would be expected to cover an area about 37 times the area of the

---

a/ For a complete discussion of discharge and projected qualitative impacts, see US EPA, 1983.

b/ Based on observed impacts at present discharge areas in Boston Harbor, and a calculated deposition rate of sewage particles resulting in organic enrichment.

zone of initial dilution (2.4 mi^2) whereas moderate impacts resulting from a sedimentation rate of 92 $g/m^2/yr$ would extend over an area about 2,500 times that of the zone of initial dilution (166 mi^2) (US EPA, 1983; Tetra Tech, 1980).

The effects of these benthic changes on commercial fisheries are not immediately clear. In general, the reduction and changes in benthic fauna are expected to result in a decrease in available foods for finfish, crabs, and, to a lesser extent, lobsters over a 166 mi^2 area of Massachusetts Bay. Unfortunately, it is extremely difficult to quantify the exact magnitude of these effects on finfish and lobster productivity.

The part of this study area which is most likely to be affected by the proposed ocean outfall, and which also supports lobster populations, is the area of the Brewsters Islands on the perimeter of Boston Harbor and Massachusetts Bay. It is possible that an area of lobster exclusion may be formed around the Brewsters based on observed exclusions at the existing Lynn Wastewater discharge (Tetra Tech, 1982). This exclusion would result, however, in only a small reduction in total lobster catch. This is because the amount of lobster caught in the Brewster Islands area represents only a fraction of the over 2 million pounds of lobster harvested in the entire area (which extends from Lynn to Scituate, and includes inner Boston Harbor). Insufficient data on the number of pounds of lobster caught in this area prevents precise quantification of these effects.

Estimates of costs to commercial finfishery are equally difficult to determine. As was the case for lobsters, increased concentrations of pollutants are expected to detrimentally affect many of the fish populations. Fin erosion, particularly in winter flounder, is one of the few impacts which are directly observable. Fin erosion has been detected in winter flounder taken from inshore Harbor locations, although the exact cause of fin erosion is not known. There is some evidence that fish develop the disease when maintained in contact with contaminated sediments. There is also additional evidence that PCBs may be involved in the development of the disease (US EPA, 1983; Sherwood, 1982). Based on this information, it is predicted that finfish (particularly the winter flounder, which will be attracted to the sediments because of their organic enrichment) will be affected by this disease. Given the lack of information on how this disease specifically alters species productivity and recruitment, however, it is currently not possible to quantitatively estimate these effects on the economics of commercial finfishing in the study area.

One final concern is the problem of toxic pollutants. Toxic pollutants and pesticides can exert a number of adverse effects on marine organisms. The ocean outfall option is expected to increase the concentrations of a number of toxic pollutants in the ambient waters and sediments surrounding the ocean outfall diffuser. Based on analysis by Tetra Tech (1980) and US EPA (1983), it is predicted that copper, mercury, silver, and PCBs may exceed EPA water quality criteria after initial dilution, unless alleviated by a toxic control program. Although an initial dilution of 133:1 will help assure that metals concentrations will fall below EPA water quality criteria, the unusually large predicted volume of particulate matter and its associated toxic substances are likely to result in high sediment concentrations of particulate-associated toxicants which will adversely affect marine biota (US EPA, 1983). Lobsters are particularly sensitive to copper concentrations; however, there is uncertainty about the sublethal, chronic effects of this heavy metal on lobster population dynamics. Even less is known about synergystic pollutant effects on both finfish and lobster.[a/]

Although toxic materials may be bioaccumulating in lobster and finfish tissue and adversely affecting the dynamics of these populations, we must conclude that because of insufficient biological, chemical and economic data, the economic effects on these commercial fisheries must remain unquantified.

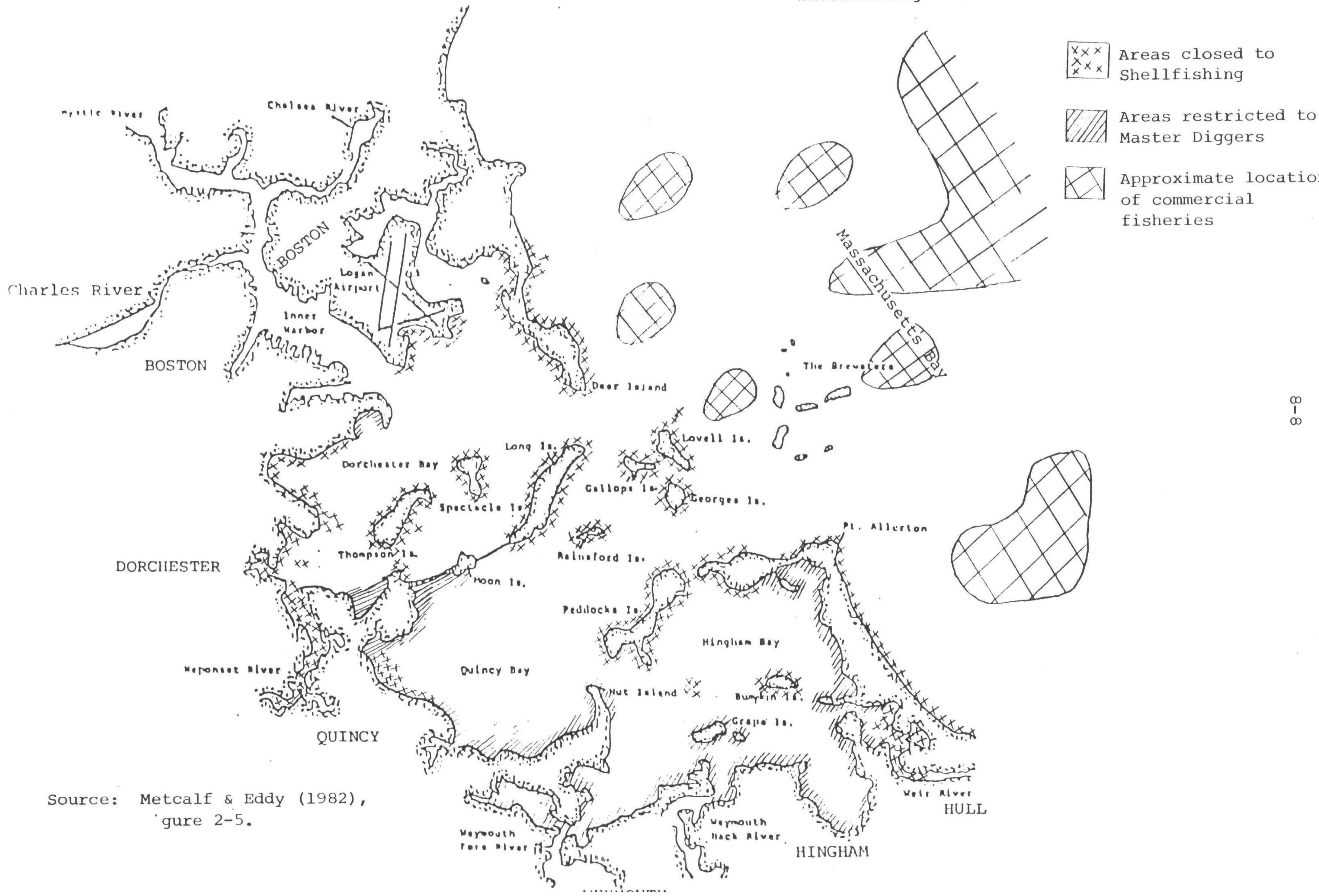
8.2 Commercial Shellfishing Industry

The shellfishing industry is the sector of commercial fishing to which the greatest value could accrue from CSO or STP pollution abatement in Boston Harbor. The soft shelled clam (Mya arenaria) is the most abundant commercially valuable shellfish species found in Boston Harbor. Blue mussels (Mytilus edulis) are also found but are not commercially valuable. The Boston Harbor fishery is an important part of the Massachusetts shellfishing industry; approximately twelve percent of the 1981 soft shelled clam harvest came from the area. There are fifty-six shellfish areas in Boston Harbor defined by the Massachusetts Division of Marine Fisheries, ranging in size from one that is three acres in Weymouth to one of 400 acres in Hingham (see Figure 8-1.). Total shellfish acreage is about 4,700 acres (see Table 8-1). Almost one-half of this acreage (2,273) is classified as grossly contaminated and, therefore, closed to harvesting. Slightly over one-half is classified as moderately contaminated and is open to harvesting only by licensed master

---

a/ Despite the fact that toxic pollutants are expected to adversely affect the marine biota, bioaccumulation of these toxic chemicals are not expected to exceed the FDA tolerance level for finfish and lobster (US EPA, 1983).

Figure 8-1. Commercial Finfishing and Shellfishing Resources in Boston Harbor



Source: Metcalf & Eddy (1982), ·gure 2-5.

Table 8-1

Characteristics of Boston Harbor Shellfish Areas[a]

Name of Adjacent City or Town or Land Area	Number of Shellfish Areas	Acreage by Classification[b] Closed	Restricted
Constitution Beach Area	10	470	426
Winthrop	3	38	316
East Boston	7	432	110
Dorchester Bay Area	4	425	70
South Boston	2	125	40
Dorchester	2	300	30
Quincy	11	581	777
Weymouth	7	129	272
Hingham	3	37	464
Hull	8	172	344
Boston Harbor Islands:	13	689	105
Slate	1		30
Grape	1		55
Bumpkin	1		20
Georges	1	28	
Lovells	1	106	
Gallups	1	20	
Deer	1	18	
Long	1	106	
Spectacle	1	46	
Thompson	1	180	
Rainsford	1	37	
Sheep	1	18	
Peddocks	1	130	
TOTAL FLAT AREA	56	2,503	2,458
Estimated Productive Tidal Area	2,300 acres	1,150	

a/ Department of Environmental Quality Engineering estimates.

b/ These acreages represent total flat area as opposed to tidal area. Productive acreage may be much smaller.

diggers and their employees. None of this area is open to unrestricted digging. Special requirements such as the posting of a surety bond are placed upon those who are issued master digger licenses by the state. Shellfish from moderately contaminated areas must undergo depuration at the Shellfish Purification Plant in Newburyport, Massachusetts, before being sold. The Massachusetts shellfish sanitation program classifies shellfish areas by standards developed by the U.S. Public Health Service and member states of the Cooperative Program for Certification of Interstate Shellfish Shippers. Among other criteria, areas are classified according to the MPN (mean probability number) of total coliform bacteria per 100 ml of the overlying waters. Zero to seventy MPN is defined as clean, seventy-one to seven hundred MPN is defined as moderately contaminated (restricted) and above 700 is defined as grossly contaminated (closed). Although bacterial quality of the water is one criteria, the guidelines contain other requirements so that any potential sources of pollution, direct or indirect, may be sufficient to declare an area unfit even though bacterial limits were met.

8.2.1 Pollution Abatement Impacts

The implementation of CSO controls or STP improvements can be expected to reduce the fecal and total coliform counts in the waters overlying the shellfish areas in Boston Harbor, as discussed in the previous chapters. Table 8-2 illustrates the changes that might occur in the classification of shellfish bed acreage if the CSO and/or STP controls were implemented. The anticipated changes would mean reclassification from grossly contaminated (closed) to moderately contaminated (restricted), thereby allowing harvesting

Table 8-2. Estimated Potential Impacts of Pollution Abatement Options on Boston Harbor Shellfish Areas [a]

Adjacent Land Area	Potential Additional Acres Open to Restricted Harvesting due to Control Option [b] — Option: CSO Const.	CSO Dorch/Nep.	CSO Quincy	STP Ocean Outfall or Secondary Trmt.	Optimum Annual Yield For Each Area (bu/acre) [c]	Increased Yield Due to Control Option (bu/yr): CSO Const	CSO Dorch./Nep.	CSO Quincy	STP Ocean Outfall or Secondary Trmt.
Winthrop	5	--	--	14	50.0	250	--	--	700
East Boston	55	--	--	161	50.0	2,750	--	--	8,050
South Boston	--	16	--	--	62.5	--	1,000	--	--
Dorchester	--	75	--	--	50.0	--	3,750	--	--
Quincy [d]	--	--	80	6	16.2	--	--	1,296	97
	--	--	20	1	50.0	--	--	1,000	50
Weymouth	--	--	--	6	50.0	--	--	--	300
Hingham	--	--	--	2	50.0	--	--	--	100
Hull	--	--	--	9	50.0	--	--	--	450
Boston Harbor Islands:	--	--	--	277	--	--	--	--	18,447
Long [d]	--	--	--	56	35.7	--	--	--	1,999
	--	--	--	31	200.0	--	--	--	6,200
Spectacle	--	--	--	6	5.0	--	--	--	30
Thompson	--	--	--	180	55.6	--	--	--	10,008
Rainsford	--	--	--	1	60.0	--	--	--	60
Peddocks	--	--	--	3	50.0	--	--	--	150
TOTAL	60	91	100	476		3,000	4,750	2,296	28,194

Sources: Based on discussions with Department of Environmental Quality Engineering and Division of Marine Fisheries staff.

[a] These are general estimates; areas must be extensively surveyed and sampled prior to any actual reclassificaton.

[b] These acreages represent productive tidal areas. Where estimates of productive tidal area were unavailable, one-half of total flat area was used as an average figure.

[c] Where optimum yield data were unavailable, 50 bushels per acre was used as an average figure (see Harrington, no date).

[d] Two rows are used for these sites because they are composed of two parts with distinctly different optimum annual yields.

with depuration. It is not likely that areas now classified as restricted could be opened to unrestricted harvesting, due to such factors as sediment contamination which are unaffected by CSO controls or STP upgrading.

It should be noted that, while this analysis specifically looks at two main factors affecting the Boston Harbor shellfisheries' soft-shelled clams (CSOs and STP discharges), other factors will also have an impact (e.g., winter-kills on the clam beds and harbor maintenance through channel dredging). Also, as mentioned above, criteria other than bacterial levels are used to classify shellfish harvesting areas.

Based on information from the Massachusetts Department of Environmental Quality Engineering, about 725 acres could be reclassified if all pollution abatement options were implemented. This represents about 30 percent of the estimated total productive tidal area (as opposed to total flat area, see Tables 8-1 and 8-2) in the harbor and about 60 percent of the closed productive tidal area. The reclassification of acreage presented in Table 8-2 must be considered as only a general estimate. Areas would have to be surveyed and sampled extensively after implementation of any of the options before any reclassification could take place.

In order to determine the impact of the pollution abatement options on the shellfishing industry, it is necessary to translate the potential addit'onal acreage open to restricted digging into an increased harvest which can be valued economically. To do this, an estimated optimum yield factor is used (see Table 8-2). The optimum yield is an estimate of the ideal annual level of harvest of a particular area which will maximize both present and future economic revenues derived from the fishery. It is based on the maximum sustainable yield (MSY), which is a biologically determined level indicating the annual harvest rate at which the productivity of the resource is maximized. Any change from this level of fish catch, more or less, would result in a decrease in the equilibrium population of fish. Optimum yield differs from MSY in that it also accounts for fishing industry effort levels and benefits to society at large (see Pierce and Hughes, 1979). The optimum annual yield of a fishery is a function of costs and expected returns as well as the natural rate of growth of the fish population. It may be a different number than the MSY and, theoretically, allows for a profit-maximizing firm to deplete the resource. It is not expected that the pollution controls in question would lower the growth rate of shellfish in affected areas, so current optimum yields have been used here.

The production and yield of a shellfish resource is generally determined from a population density study of the area which place clams into class sizes seed, juveniles, intermediates and mature in the order of size groupings. These results afford information on the generation of yearly stock and of succeeding crop families. Data also is produced on the health of the shellfish, predation and a general distribution pattern of the shellfish in the area. The information on optimum yield in Table 7-2 was provided by the Massachusetts Department of Environmental Quality Engineering. Where no studies have been made an average figure of 50 bushels per acre was used.[a]

---

a/ From Harrington (no date). Also, the Maine Department of Marine Resources rates acreage productivity for less than 25 bu/acres as poor, for 25-50 bu/acre as fair, for 50-75 bu/acre as good and for greater than 75 bu/acre as excellent (provided by E. Wong, Environmental Protection Agency, Region I, Boston, MA).

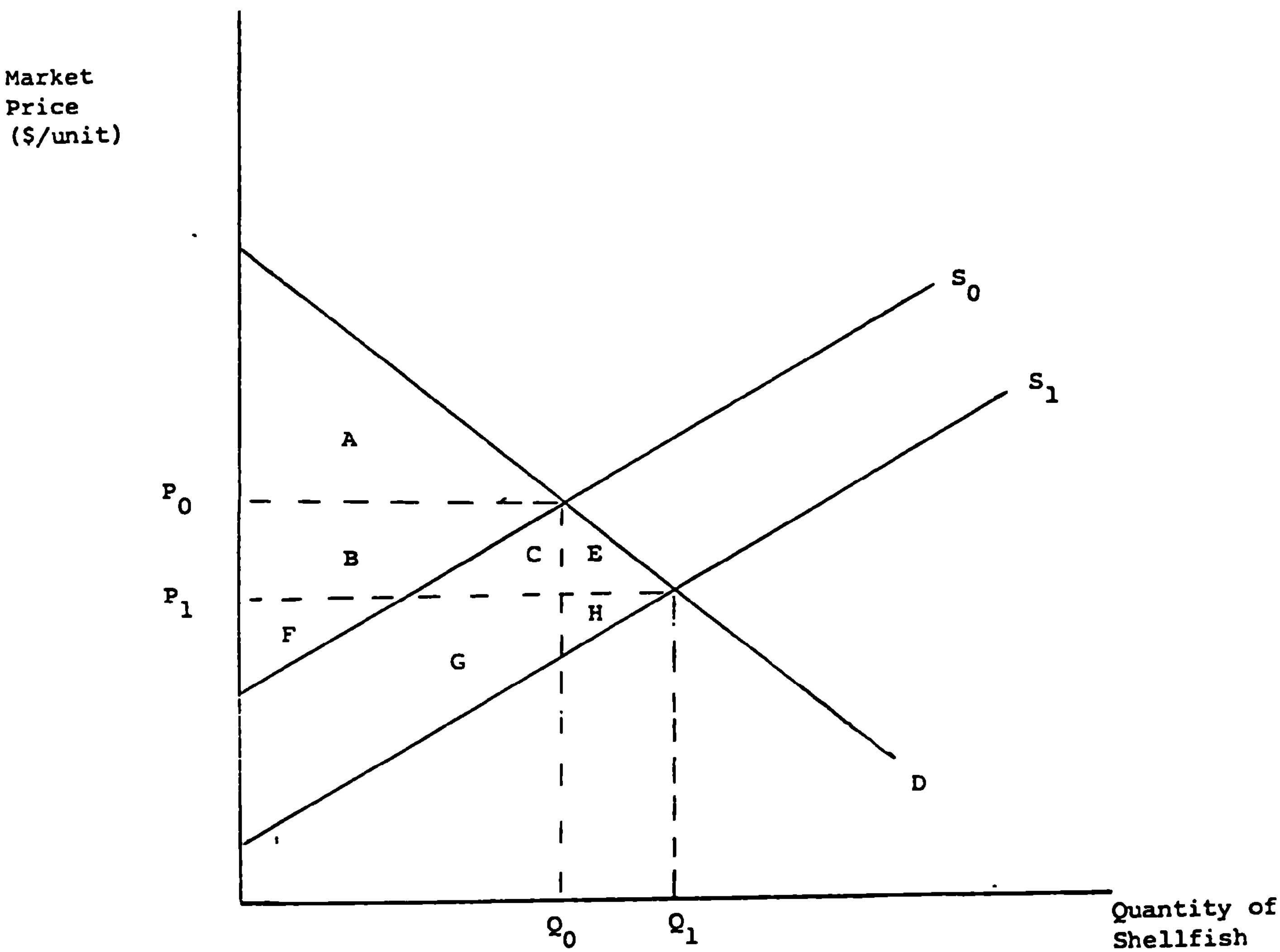
Multiplying the optimum annual yield by the acreage potentially reclassified due to each abatement option gives the increased annual yield that could be realized, as shown in the last four columns of Table 8-2. The economic benefits associated with these increased yields depend upon the economics of the industry and the supply and demand for soft shelled clams, as discussed below. It should be noted that compared with an estimated current 16,000 bushels annual yield in Boston Harbor, the maximum estimated increase of 34,000 bushels from all pollution abatement options amounts to twice the current annual yield. This potential increase would impact on the depuration plant, patrol surveillances, and laboratory and water quality monitoring. These factors could act to limit actual acreages opened to increased harvesting.

8.2.2 Benefit Assessment Methodology

Two types of benefits--change in producer surplus and change in consumer surplus--may be associated with an increased shellfish harvest resulting from pollution abatement. Producer surplus is a measure of the well-being of a firm and is defined as the excess of revenues over costs. Figure 8-2 illustrates typical, simplified demand (D) and supply (S_0) curves for the shellfish industry. In the figure, producer surplus is the area below the price line (P_0) and above the supply curve (S_0); it is equal to the area labeled "B" plus the area labeled "F". Consumer surplus is a measure of the satisfaction a consumer derives from the purchase of goods and services and is defined as the difference between what the individual is willing to pay and what is actually paid. In Figure 8-2, consumer surplus is the area above the price line (P_0) and below the demand curve (D) (i.e., the area labeled "A").

Figure 8-2.

Typical Demand and Supply Curves for the Shellfish Industry



If the fishery is regulated and managed so that free entry by new firms is restricted, then a change in producer surplus may occur. If the increase in harvest is accompanied by either an unchanging price level or by a decrease in per unit harvest costs greater than the decrease in price, then increased profits will accrue to those firms in the restricted fishery throughout the time frame of the analysis. If entry is unrestricted, however, then the increased profits or rents to existing firms would be dissipated (after several years duration at best) as new firms are attracted to the industry, resulting in no long-run producer surplus.

A change in consumer surplus would depend upon a change in market price. If the increase in harvest is large relative to the total local market, then the market price could decrease, resulting in an increase in consumer surplus. If the increase in harvest is relatively small, or if the industry is oligopolistic (i.e., composed of only a few firms so that each can affect the whole industry) and the firms influence market price, then the price might not decline and no increase in consumer surplus would accrue.

Whether changes in either producer or consumer surpluses would result from the increased shellfish harvest estimated in the previous subsection for the pollution abatement options depends upon the shapes of the demand and supply curves for the industry. As mentioned above, in Figure 8-2 for price equals P_0 and quantity equals Q_0, consumer surplus is defined as the area A and producer surplus as the sum of the areas B + F. In the case illustrated, an increase in quantity to Q_1 along with a downward shift in the supply curve from S_0 to S_1, representing a decrease in per unit harvest costs (resulting from pollution abatement), results in a new lower equilibrium price, P_1. In this hypothetical example, both consumer and producer surpluses are increased and these changes can be valued as economic benefits associated with the pollution abatement, as follows:

Change in consumer surplus (CS)	=	New CS - Old CS
	=	(A + B + C + E) - A
	=	B + C + E
Change in producer surplus (PS)	=	New PS - Old PS
	=	(F + G + H) - (B + F)
	=	G + H - B.

These supply and demand curves must be estimated empirically for the relevant benefits to be determined. For example, if the demand curve is very elastic (i.e., flat) in the region of interest, then we can expect no significant consumer surplus benefits to accompany an increase in quantity produced. Broadly speaking, demand is elastic if quantity demanded is highly responsive to price changes and is inelastic if it is not. A very elastic demand curve would be one that is approaching a horizontal line and, therefore, the change in consumer surplus (B + C + E in the above example) would be very small. Or if, for instance, the supply curve for the industry is not upward sloping in the region of concern, then no producer surplus would be associated wth the production increase. Benefits estimated for a particular fishery could include either consumer surplus benefits only or producer surplus benefits only, or both types together, or no long-term benefits, depending upon the shapes of the empirically estimated curves and whether or not the fishery is regulated (i.e., entry restricted).

8.2.3 Benefit Estimates

Although the theory for estimating commercial fishing benefits is well developed and straightforward, the application of that theory is difficult. There are no readily available studies which define consumer demand or supply curves for the soft shelled clam industry in Massachusetts or elsewhere.

Landings data (data on the quantity of shellfish harvested) are collected by the state but are felt to be reasonably accurate only for recent years. Exvessel price (price to the digger or firm) data are not available. The Boston area, however, is a major market for the industry. In 1980 consumption was estimated at approximately 625,000 bushels.[a/] Only 20 percent of that quantity was harvested in Massachusetts, about 125,000 bushels. About 20 to 25 percent was harvested in Maryland and the remainder in Maine. Maine and Maryland collect more extensive price and landings data than does Massachusetts.

A study was done in Maryland in the mid-1970s for various fisheries in the Chesapeake Bay, including the soft shelled clam fishery (Marasco, 1975). This study developed the following demand function for the soft shelled clam fishery, calibrated to late 1960s landings and price data in Maryland:

$$\log Q = 2.4606 - \underset{(-9.5022)^{b/}}{2.3588} \log (P/CPI) + \underset{(.9463)}{.6067} \log (I/CPI) \qquad R^2 = .91$$

where,

Q = landings in 1,000 lbs.
P = exvessel price in ¢/lb.
I = per capita income
CPI = consumer price index.

Price elasticity of demand is defined as the ratio of the relative change in quantity to the relative change in price, i.e., $(\Delta Q/Q)/(\Delta P/P)$. The price elasticity for clams in t! above equation is -2.3588. Price elasticities for other species included in this study ranged from -.1 to -2. (See Appendix D.1 for a discussion of other demand curves investigated.)

---

a/ Based on Division of Marine Fisheries estimates.
b/ Significant at the .01 level.

Unfortunately, the above demand function and other demand curves considered represent the total demand faced by the fishermen for their product which is shipped to more than one consumer market and not all consumed in Maryland. So the estimated price elasticity (-2.3588) cannot be automatically applied to develop a demand curve for Massachusetts consumers, even if the markets were assumed comparable. The price elasticity for Massachusetts consumers might be higher than the one in the above equation because many other fish species might be considered close substitutes. On the other hand, it has been said that demand for soft shelled clams in Massachusetts in the summer is unlimited; any that can be dug can be sold because of the high tourist demand for this well-known local specialty.

To account for the lack of data, consumer demand functions have been estimated for Massachusetts for a particular year (1981) for a range of price elasticities, from more elastic (-3) to less elastic (-.5) than the number in the above equation. Given the changes in yield estimated in the previous subsection for each pollution abatement option and given an estimated average price for that year ($31.41/bu[a/]), new prices were estimated for each assumed price elasticity. The demand equation used is of the following form:

$$Q_{82} = A \times P_{82}^{\alpha} \quad \text{or,}$$

$$\log Q_{82} = \text{Log } A + \alpha \times \text{Log } P_{82}$$

---

a/ Based on Resources for Cape Ann, 1982, price for 1980 ($28.00) updated to 1982 price using soft shelled clams price index from National Marine Fisheries Service, NOAA, 1983.

where,

Q_{82} = quantity consumed in the Boston market in 1982
A = constant
α = assumed price elasticity
P_{82} = average 1982 exvessel price for soft shelled clams in Massachusetts.

Table 8-3 displays the results of these estimates. The table shows that as price elasticity increases (from -.5 to -3) and the demand curve becomes flatter, the price changes resulting from the increases in clam harvest due to the abatement options, decrease. The price decrease is greatest for the combined CSO and STP upgrade option with an inelastic demand curve assumed (α= -.5). The price change is least for the CSO options (taken separately) with an elastic demand curve assumed (α= -3).

For reasons which are described below, it is likely that the primary source of commercial fisheries benefits that would be associated with the pollution abatement options would result from changes in consumer surplus rather than producer surplus. If no producer surplus changes occur (see below), then total commercial fisheries benefits (equal to change in consumer surplus) would be as shown in Table 8-4, following the same price elasticity assumptions that were made for Table 8-3.

Consumer surplus benefits (Table 8-4) are estimated from the price changes shown in Table 8-3 and from the changes in yields previously estimated for each abatement option (see Table 8-2). These changes in consumer surplus were calculated from the following equation:

$$\Delta CS = \Delta P \times Q_o + 1/2 (\Delta P \times \Delta Q)$$

where,

ΔCS = change in consumer surplus ($)
ΔP = change in price ($)
Q_o = initial consumption (bushels)
ΔQ = change in consumption (bushels).

Table 8-3. Estimated Changes in Price of Soft Shelled Clams Associated with Alternative Abatement Options and with Assumed Price Elasticities of Demand (1982$)

Abatement Option		Elasticity (α) -.5	-1	-2	-3
CSO					
Constitution	Price	31.11	31.26	31.33	31.36
	ΔP	-.30	-.15	-.08	-.05
Dorchester/Neponset	Price	30.94	31.17	31.29	31.33
	ΔP	-.47	-.24	-.12	-.08
Quincy	Price	31.18	31.30	31.35	31.37
	ΔP	-.23	-.11	-.06	-.04
Combined CSO[a/]	Price	30.42	30.91	31.16	31.24
	ΔP	-.99	-.50	-.25	-.17
STP: Ocean Outfall or Secondary Treatment	Price	28.76	30.05	30.72	30.95
	ΔP	-2.65	-1.36	-.69	-.46
Combined CSO and STP[a/]	Price	27.89	29.60	30.49	30.79
	ΔP	-3.52	-1.81	-.92	-.62

[a/] All CSO options are combined in this row. Price changes are greater for the combined plans than for the sum of the separate plans, because the demand equation is not linear.

Table 8-4. Estimated Total Benefits
Associated with Alternative Abatement Options
and with Assumed Price Elasticities of Demand (1982$)

Abatement Option	Elasticity (α) -.5	-1	-2	-3
CSO				
Constitution	5,239	2,626	1,314	877
Dorchester/Neponset	8,674	4,353	2,181	1,455
Quincy	3,936	1,971	987	658
Combined CSO	20,727	10,446	5,243	3,501
STP: Ocean Outfall or Secondary Treatment	79,847	40,804	20,627	13,812
Combined CSO and STP	123,537	63,602	32,273	21,622

It was assumed that the harvest from Boston Harbor shellfish areas is consumed in the Boston area market. In addition, 16,000 bushels was used as a reasonable estimate of the annual harvest from Boston Harbor restricted areas before pollution abatement and, therefore, as the initial consumption estimate (Q_o)[a/]. For a more detailed discussion of the computation methods used to obtain the new prices, price changes and consumer surplus benefits, see Appendix D.2.

As shown in Table 8-4, the total benefit levels vary in roughly the same way as the price changes shown in Table 8-3. This is because as the price decreases, the difference between price and willingness to pay increases, so that consumer surplus increases, and is shown by positive numbers in the table. The greatest benefits are obtained from the options with the greatest increase in yield and the most inelastic demand. Total benefits are larger for the combined options than for the sum of the separate options, because the demand equation is not linear.

It could also be legitimately argued that the change in consumer surplus could be zero. If all the pollution abatement options were implemented, then the increased harvest (34,000 bushels) would represent about six percent of the total market (625,000 bushels). Since it appears that none of the firms included in the Boston area market can influence price and since only a small percentage of them would be affected by the pollution abatement, it could be reasonably agreed that there would not be a change in consumer surplus given the small percentage increases in harvest just mentioned. Not enough is known about the consumer demand curve, however, to make a definitive judgment.

---

a/ Division of Marine Fisheries

Thus, from the considerations just discussed, we can conclude that the range of commercial fisheries benefits resulting from implementation of the pollution abatement options in Boston Harbor would be from zero to the higheststimates.levels presented in Table 8-4. The benefits estimates shown in Table 8-4, column 2 (price elasticity = -1) represent moderate levels between the upper and lower bounds just described.

As indicated above, no definitive estimates concerning producer surplus changes could be made due to lack of data. Attempts were made to develop a supply curve but were unsuccessful; these are described in Appendix D.3 along with an example showing how to compute change in producer surplus, if such benefits exist.

A reasonable argument can be made that the change in producer surplus would be zero for commercial shellfishing in Boston Harbor. This argument is that the supply curve is flat in the range of interest. If there is unlimited entry of firms into the fishery, then the additional profits or rents which would accrue to the master diggers currently operating in Boston Harbor restricted areas would be dissipated over the long run, leaving no long-term producer surplus benefits. There do exist institutional constraints on entry to the fishery; the State of Massachusetts places some restrictions upon master diggers allowed to operate in moderately contaminated areas: they must have a special license, post a surety bond, utilize specially licensed employees, meet certain transport requirements, keep certain records and are not allowed to concurrently harvest in areas classified as closed. There are no absolute restrictions to entry, however; as long as a firm meets the requirements, it may participate.[a]

---

[a] For a discussion of various options for entry or effort regulation of New England fisheries, see Smith and Peterson, 1977.

In addition to the question of official restrictions on entry into the Boston Harbor shellfishing industry there is also evidence, as mentioned in the Section on Health Benefits, that thousands of bushels of contaminated clams are being bootlegged (illegally harvested) from the shellfish areas that are classified as closed by the state.[a/] This evidence shows that the official restrictions on Boston Harbor shellfishing are often ignored and that in practice there are few barriers to entry. It is, therefore, probable that the change in producer surplus that would result from the control options would only extend over a limited number of years until new firms attracted by the increased profits are able to meet the entry requirements. It is impossible to say how long these impediments would prevent new entries, but over the long term they may not keep the additional profits generated by the pollution abatement options from being reduced to zero.

8.2.4 Limits of Analysis

The major limitation of this analysis of commercial fisheries benefits is the lack of well-developed consumer demand and supply curves for the soft shelled clam industry. This makes application of the theory for estimating commercial benefits difficult. However, it is unlikely that a producer surplus exists and the true demand elasticity probably falls within the estimated demand elasticity range used in this study. Thus, the analysis was able to put bounds around the uncertainty.

Other data deficiencies include no good historical data for Massachusetts on harvest of soft shelled clams, numbers depurated and price to the digger. Little information also exists on the Boston consumer market and its sources and changes over time. Furthermore, there is only a small amount of data on

---

a/ Discussions with Division of Marine Fisheries staff and others.

costs of the firms in the industry, particularly those with special licenses to operate in restricted areas. The impacts of pollution abatement and of theresulting increase in yields on these costs are hard to judge, especially the changes in numbers of employees and income to the master diggers. This lack of data thus prevented a more precise estimation of shellfishing benefits.

References

Altobello, Marilyn A., David A. Storey and Jon M. Conrad, January 1977. The Atlantic Sea Scallop Fishery: A Descriptive and Econometric Analysis, Research Bulletin No. 643, Massachusetts Agricultural Experiment Station, University of Massachusetts, Boston, MA.

Arnold, David, January 31, 1983. Clammers Can't Work, Can't Get Benefits, The Boston Globe, Boston, MA.

Cape Cod Planning and Economic Development Commission, 1978. An Economic Profile of the Cape and Islands Fisheries.

Commonwealth of Massachusetts, Division of Marine Fisheries, 1981. Abstracts of Massachusetts Marine Fisheries Law, Boston, MA.

Commonwealth of Massachusetts, Division of Marine Fisheries, March 1982. Massachusetts Marine Fisheries Management Policy Report, Boston, MA.

Commonwealth of Massachusetts, Division of Marine Fisheries, 1982. Rules and Regulations Pertaining to the Issuance and Use of Master and Subordinate Digger Permits, Boston, MA.

Commonwealth of Massachusetts, Division of Marine Fisheries, 1982. Shellfish Areas Approved for Restricted Harvest with Depuration and Corresponding Routes to Newburyport Purification Plant, Boston, MA.

Crutchfield, Stephen R., February 1983. Soft Clam Exvessel Demand Functions and Clam Fishery Data, unpublished data, Department of Resource Economics, University of Rhode Island, Kingston, RI.

Dumanoski, Dianne, December 19 to 21, 1982. Boston's Open Sewer, three part series, The Boston Globe, Boston, MA.

Harrington, Peter, (no date). Shellfish Resource Estimates, unpublished memo, Massachusetts Department of Environmental Quality Engineering, Boston, MA.

Marasco, Richard J., May 1975. An Analysis of Future Demands, Supplies, Prices and Needs for Fishery Resources of the Chesapeake Bay, MP 868, Agricultural Exper.' ent Station, University of Maryland, College Park, Maryland.

Marchesseault, Guy, Joseph Mueller, Lars Vidaeus and W.. Gail Willette, 1981. "Bio-Economic Simulation of the Atlantic Sea Scallop Fishery: A Preliminary Report", in K. Brian Haley (ed.), Applied Operations Research in Fishing, Plenum Publishing Corp., New York, NY.

Metcalf and Eddy, Inc., June 1982. Nut Island Wastewater Treatment Plant Facilities Planning Project, Phase I, Site Options Study, for the Metropolitan District Commission, Boston, MA.

National Marine Fisheries Service, NOAA, 1983. Fisheries of the U.S, Washington, DC.

National Marine Fisheries Service, NOAA, 1976. Fishery Statistics of the U.S, Washington, DC.

Pierce, David E. and Patricia E. Hughes, January 1979. Insight into the Methodology and Logic Behind National Marine Fisheries Services Fish Stock Assessments, Massachusetts Division of Marine Fisheries and Coastal Zone Management Office, Boston, MA.

Resources for Cape Ann, April 1982. The Costs of Pollution: The Shellfish Industry and the Effects of Coastal Water Pollution, Massachusetts Audubon Society.

Sherwood, M.J. 1982. Fin Erosion, Liver Condition, and Trace Contaminant Exposure in Fishes from Three Coastal Regions. In: "Ecological Stress and the New York Bight," Science and Management, pp. 359-377. Estuarine Research Federation, Columbia, South Carolina.

Smith, Leah J. and Susan B. Peterson, August 1977. The New England Fishing Industry: A Basis for Management, Technical Report WHOI-77-51, Woods Hole Oceanographic Institution, Woods Hole, MA.

Tetra Tech, Inc. 1980. Technical Evaluation of Deer Island and Nut Island Treatment Plants Section 301(h) Application for Modification of Secondary Treatment Requirements for Discharge into Marine Waters for U.S. Environmental Protection Agency.

Tetra Tech, Inc. 1981. Technical Evaluation of Lynn Wastewater Treatment Plant Section 301(h) Application for Modification of Secondary Treatment Requirements for Discharge into Marine Waters, for U.S. Environmental Protection Agency.

Townsend, Ralph and Hugh Briggs, September 1980. Some Estimates of Harvesting and Processing Costs for Maine's Marine Industries, technical report, Department of Economics, University of Maine.

U.S. Environmental Protection Agency, Economic Analysis Division, 1982. The Handbook of Benefit-Cost Assessment for Water Programs, Draft, Washington D.C.

U.S. Environmental Protection Agency, Office of Marine Discharge Evaluation, 1983. Analysis of the Section 301(h) Secondary Treatment Waiver Application for Boston Metropolitan District Commission, Washington, D.C.

Wang, Der-Hsiung, Joel B. Dirlam and Virgil J. Norton, March 1978. Demand Analysis of Atlantic Groundfish, (preliminary report), Staff Paper No. 7, Agricultural Experiment Station, University of Rhode Island, Kingston, RI.

Williams, Doug, (no date). Data and Procedures Used to Estimate Technical Coefficients for the Clam/Worm Sector, unpublished paper, Department of Agricultural and Resource Economics, University of Maine.

Section 9
Intrinsic Benefits

Intrinsic benefits are all benefits that are associated with a resource, which are not specifically related to current direct use of that resource. Although these non-user benefits are not directly observable, it is important to emphasize that they are as real and economically important as the more easily measured user benefits.

Briefly, intrinsic benefits can be categorized as the sum of option (bequest) values, existence value, and aesthetics.[a/] Option value is defined as the amount of money, beyond user values, that individuals are willing to pay to insure access to the resource (or a level of environmental quality) in the future when there is uncertainty in resource availability and/or individual use (demand), regardless of whether the individual is a current user. Option benefits reflect the value of reducing uncertainties and of avoiding irreversibilities. When option values reflect intergenerational concerns they are referred to as bequest motives. Bequest values are defined as the willingness to pay (WTP) for the satisfaction associated with endowing future generations with the resource. Existence value is defined as the willingness to pay for the knowledge that the resource is available and ecosystems are being protected, independent of any

---

[a/] For an in depth discussion of intrinsic benefits and their estimation, see RTI, 1983; Freeman, 1979; Fisher and Raucher, 1982; Mitchell and Carson, 1981.

anticipated use by the individual. These values are distinct from aesthetic benefits and concerns over retaining the option of future use. Aesthetic values pertain to enhanced appreciation of water-related (instream vs. near stream) experiences. Given that improved water quality could enhance the aesthetic values of users as well as non-users of the resource, there could be an aesthetic component in both use benefits and intrinsic benefits.

Definitions of bequest values tend to obscure the distinction between existence and option values in the literature. Sometimes bequest values are placed in a separate category of intrinsic values; sometimes they are treated as part of existence values and at other times they are considered as option values. For example, Freeman (1979) considers the utility of the expectation of future use by descendants as a bequest form of vicarious existence benefits. Yet, bequest values can be considered for long term potential use where there may be uncertainties associated with future demand and supply. Hence, this concept may be treated as part of option value. Mitchell and Carson (1981), for example, separate option value into current and bequest categories.

Although the distinction between user and intrinsic benefits is often unclear, there is substantial agreement that these intrinsic benefits may account for a large portion of all pollution abatement benefits (see Fisher and Raucher, 1982). Intrinsic benefits are usually derived from lemand functions. Data for these functions are most frequently obtained from surveys, questionnaires, and voting referenda. Assuming that people are willing to pay for these values, these techniques are intended to yield information on the prices that consumers are willing to pay for cleaner water even though they do not intend to use the resource directly. This generated price information is used to construct demand equations from which the welfare changes associated with cleaner water can be measured. Despite the criticisms leveled at this contingent valuation approach, due to several potential biases, the survey method represents the best available technique to quantify all these benefits.

Property value data may also be used to infer estimates of intrinsic benefits. The property value approach is based on the hedonic valuation method, which relates the price or value of a property to a variety of discrete characteristics. These characteristics include site and neighborhood characteristics, socio-economic factors, and environmental quality variables such as degree of water pollution. A major limitation of the property value technique is that it neglects the benefits to those who do not own property near the affected water body. The approach also records the response of property owners to an actual change in water quality, a change which may not necessarily reflect what property owners would be willing to pay for potential improvements in water quality, or for improved water quality at other locations. As a result, a significant fraction of value, in the form of consumer surplus, may be omitted when applying this technique. In addition, the hedonic approach may produce biased benefit estimates because of the difficulty in disaggregating the benefits between use (recreation, for example) and nonuse. There have been several attempts to model this relationship despite the extensive data required for this technique. One such effort, described in Feenberg and Mills (1980), uses property values derived from a study by Harrison and Rubenfeld (1978).

9.1 Methodology

Intrinsic benefits are difficult to measure and value. A number of studies have attempted to measure intrinsic values using the WTP survey approach. We know of no specific study that can be applied directly to the entire Boston Harbor or that can be associated with the range of pollution abatement options which accurately relates either dichotomous or incremental changes in water quality to corresponding changes in intrinsic values. The most recent willingness to pay surveys measure benefits to users and non-users of rivers (RTI, 1983; Cronin, 1982) and are inappropriate to apply to a marine resource such as Boston Harbor. The Gramlich (1977) study, which measures willingness to pay for improving water to a swimmable level in the Charles River, cannot be applied to Boston Harbor because Gramlich's bids are averages across both users <u>and</u> nonusers, representing <u>total</u> values, and because the Charles River is not a marine resource.

Other researchers have attempted to establish a relationship between intrinsic values and user values (see Fisher and Raucher, 1982, for a critical review). Results from this approach suggest that intrinsic values are substantial: they generally are at least one-half as great as recreational user benefits. Because of the lack of appropriate WTP survey data which can be applied to the different control options in the study area, estimates of intrinsic benefits were made by assuming that these non-user benefits are one-half as great as recreational user benefits.

9.2 Benefits Estimates

Intrinsic benefits for the CSO and STP pollution control options are accordingly based on one-half the benefit estimates derived from the recreational benefits estimated in Section 6.[a/] These benefit values

---

a/ Includes swimming participation (logit model plus Quincy, Weymouth, Hingham, Hull and Nantasket estimates), boating, fishing, and Boston Harbor Islands recreation. For swimming the user day value ($11.06) derived in the logit model is applied to increased user day figures (see text in Section 6 for user day values for other recreational activities).

incorporate both current and future benefits from water quality improvements and are presented in Table 9-1. The range of values represents a very rough approximation of non-user benefits.

Table 9-1

Annual Intrinsic Benefits

(Millions 1982$)

		Pollution Control Option	
		CSO plus Ocean Outfall	CSO plus Secondary Treatment
50% of Recreation Benefits	High:	21.8	23.2
	Low:	10.1	10.7
	Moderate:	15.9	17.0

9.3 Limits of Analysis

Non-user benefits are especially difficult to measure and project, and estimation of these benefits is limited by both methodology and data. Appropriate willingness to pay surveys and property studies were not available to estimate benefits from the variety of pollution control options. As a result, these benefits may be biased because they might be capturing benefits calculated under other categories such as fishing, swimming, or boating (i.e., double counting).

References

Cronin, Francis, 1982. Valuing Nonmarket Goods Through Contingent Markets, Richland, Washington: Pacific Northwest Laboratory, PNL-4255.

Feenberg, Daniel and E.S. Mills, 1980. Measuring the Benefits of Water Pollution Abatement, Academic Press, New York, NY, 187 pp.

Fisher, Ann and Robert Raucher, 1982, Comparison of Alternative Methods of Evaluating the Intrinsic Benefits of Improved Water Quality, presented at the American Economics Association proceedings, New York.

Freeman, A. Myrick, 1979. The Benefits of Environmental Improvement. Johns Hopkins University Press, Baltimore, Maryland.

Gramlich, Frederick, 1977. The Demand for Clean Water: The Case of the Charles River, National Tax Journal 2:183.

Harrison, David and Daniel Rubenfeld, 1982. Hedonic Housing Prices and the Demand for Clean Air. Journal of Environmental Economics and Management 5: 81-102.

Mitchell, Robert and Richard Carson, 1981. An Experiment in Determining Willingness to Pay for National Water Quality Improvements. U.S. Environmental Protection Agency.

Research Triangle Institute, 1983. A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvement, Research Triangle Park, North Carolina.

Section 10
Ecological Effects

Several of the pollution abatement options considered are expected to have a positive influence on the ecological processes in the estuarine areas of Boston Harbor because of significant reductions in pollutant loadings and corresponding reductions in concentrations of fecal coliform, suspended solids, organic toxics, heavy metals, and increases in the level of dissolved oxygen. Implementation of the ocean outfall option is also expected, on the one hand, to beneficially impact the ecological processes in Boston Harbor while, on the other hand, to detrimentally affect the ecological processes in Massachusetts Bay because of removal of pollutants from the Harbor to the Bay.

It is not easy to capture the ecological costs and benefits of these pollution control options because of the lack of information linking pollutant transport and dispersion to specific dose-response relationships, and the difficulty in expressing these changes and effects in monetary units. Therefore, the following discussion of the ecological effects of the different treatment options will be presented qualitatively, as opposed to the quantitative benefits and costs described in previous chapters.

10.1 CSO and Secondary Treatment Options

It is likely that the CSO and STP pollution abatement options will positively influence the biological ecosystem within Boston Harbor, particularly the highly productive saltmarsh habitats. Phytoplankton, benthic organisms and the communities of shellfish, finfish and lobster will be specifically affected. This positive effect will occur because both treatment options will reduce loadings of BOD, suspended solids and fecal coliform to the Harbor area, as well as reducing concentrations of heavy metals (see Table 2-3) and possibly organic toxics such as pesticides and PCBs.[a/] Although none of Massachusetts' major saltmarshes are located in Boston Harbor, it does contain a significant amount of marsh acreage. Quincy Bay has 209 areas of saltmarsh, Dorchester Bay 363 acres, Hingham Bay 644 acres and there is also Belle Isle Marsh along the inlet in Winthrop. These marshlands play an important role in the biological productivity of the adjacent coastal waters as well as performing other useful functions. It is well documented (Odum, 1961; Teal, 1962) that these areas are the most efficient primary producing environments on earth and provide natural spawning, nursery and feeding habitat for many species of fish and invertebrates. The sheltered waters and grasses provide food and cover for furbearing animals, shorebirds, and waterfowl. From two-thirds to three-quarters of the commercially or recreationally important finfish, such as herring, striped bass and flounder, and shellfish spend part of their lifecycle in saltmarshes.

Marshlands tran form carbon dioxide water into oxygen and food. They are highly productive of organic matter; because of the tides, wastewater

---

a/ In general, the STP secondary option will reduce conventional and non-conventional pollutant loadings to a greater extent than the CSO option, although the greatest difference in reduction are changes in BOD and suspended solids.

products are regularly removed and organic material and nutrients are added. It has been estimated that a saltmarsh produces 10,000 pounds of organic matter per acre per year (Odum, 1961). These lands concentrate and recycle carbon, nitrogen and phosphorus and are important to the global cycles of nitrogen and sulfur. Marsh areas have a very high value as providers of tertiary sewage treatment since they remove and recycle inorganic nutrients.

Saltmarshes are also important for stabilizing the shoreline. They provide a buffer zone which limits coastal erosion by flood, wave, and wind action. Marshes act as reservoirs during flooding and absorb sediments and wave energy during storms which aids in keeping harbors open and in preserving beaches.

Attempts have been made to estimate the economic value of saltmarshes by valuing the productivity of the marsh, by valuing the role of the marsh as a factor of production, and by estimating the cost of duplicating the functions of a marsh, such as providing tertiary wastewater treatment. Annual values ranging from $100 to $4,000 per acre were developed in one study (Gosselink, Odum and Pope, 1973). These types of values have been criticized as representing total value rather than net benefits and much smaller values ($.25-$.30 per acre) were estimated for marsh areas as factors of production (Lynn, Conroy and Prochaska, 1981). Another study points out the many functions of the marsh are not included when only the productivity of the marsh is valued (Westmore, 1977). In any case, if, for illustration purposes, such a range of values is applied to the total marsh acreage of Boston Harbor (1216+ acres), an economic value ranging from $121,600 to $4,864,000 per year is estimated.

Whatever value of marshland is selected, the problem for this case study is determining the impact of the pollution abatement option on the marsh. For the most part, the studies cited above and others are concerned with development that will destroy the marsh by dredging or filling. Here, the concern is with the impact of pollutants (and their abatement) on the functioning of the marsh. It is known that large amounts of untreated organic materials greatly stress marshes and reduce dissolved oxygen to undesirable levels. However, smaller amounts of these materials may enhance marsh productivity. Chlorinated hydrocarbons, and organophosphorous pesticides have been measured in the Harbor in sufficient concentrations to have sublethal or lethal effects on adult crustaceans, larval mollusks and embryonic and larval forms of finfish. Other effects on saltmarsh flora and fauna are unknown.

The proposed pollution abatement options under consideration in this study will control coliform bacteria, pesticides and some heavy metals in Harbor marshlands. The connection between the levels of control and the effect on the functioning of the marshlands, however, is unknown. Since we are unable to measure the extent of the impacts, these marshland benefits must be considered nonmonetizable.

The effects on the plankton and benthic communities throughout the rest of the Harbor generally will be the opposite of those described below for the ocean outfall option. Reduction in conventional loadings may increase species diversity and there will be a shift whereby pollution sensitive-species will replace many of the pollution-tolerant species now dominating the Harbor. These community changes will influence the abundance and diversity of species who feed on these organisms in the lower portion of the food chain, leading to a shift towards pollution-intolerant species. For example, yellow tail flounder may replace winter flounder who prefer organically enriched sites.

Reductions in metals and possibly organic toxicants will have a positive effect on many species in the Harbor, particularly the shellfish and finfish who tend to bioaccumulate toxic substances such as PCBs and organically complexed metals such as mercury and lead.[a/] These effects may include a reduction in disease (such as finfish erosion), increases in juvenile survival and increases in productivity and community stability.

10.2 Ocean Outfall Option

The ocean outfall plan is expected to have negative effects on the biological ecosystem of a portion of Massachusetts Bay. As discussed in Section 2 of this report, the pollution abatement plan calls for an ocean outfall diffuser system to discharge the combined, treated effluent from Deer and Nut Island plants into Massachusetts Bay, 7.5 miles (12.1 km) northeast of Deer Island. This discharge area will not provide for sufficient

---

a/ It is important to note however, that although the pollution abatement options under consideration will eliminate some of the toxic substances and metals in the Harbor waters, significant concentrations of these pollutants reside in the harbor sediment and are constantly being re-suspended. It is not known what the flushing rate is for Boston Harbor but the rate is probably considerably reduced because of the very shallow depths of all the harbor waters. Thus, many of these pollutants will remain in the sediment and water columns for many years to come and continue to negatively affect the ecological communities.

transport and dispersion of the diluted wastewater and particulates because it is topographically depressed. This, in turn, will restrict circulation and dilution and will lead to an accumulation of BOD and suspended solids, and several toxic pollutants. In addition, the proposed discharge of suspended solids is expected to violate the Commonwealth's dissolved oxygen standard.

Discharge from the proposed outfall is expected to negatively affect the structure and function of many of the components of the marine ecosystem in this area including phytoplankton, benthic invertebrates, and communities of lobster, crab and finfish. It is also possible that several species of whales, including the endangered Right whale, will be influenced by discharge of pollutants into Massachusetts Bay.

10.2.1 Plankton

The proposed ocean discharge of BOD and suspended solids (which include toxic pollutants) is predicted to significantly enrich the waters within the immediate 2.4 square miles surrounding the diffuser and extend to a much larger zone of 166 mi^2 and thus greatly increase the levels of available nutrients such as nitrogen (the most limiting nutrient in marine waters) and phosphorous. Increased amounts of these nutrients will consequently stimulate phytoplankton productivity and lead to increases in phytoplankton biomass, as well as resulting in an adverse shift from pollutant-intolerant phytoplankton to pollutant-tolerant species. The composition and distribution of the zooplankton populations are not expected to be significantly affected because of the increased limited dilution and because the zooplankton community is inherently able to quickly recover from pollutant stress. As discussed in the waiver documents (Tetra Tech, 1980; US EPA, 1983) the most polluted of waters appear to depress numbers of zooplankton without measurably altering species composition or distribution. The only effects from these increased pollutant loadings would be a proportional decrease in actual numbers of individuals of all species.

10.2.2 Benthos

The benthic community in the proposed ocean outfall area is currently dominated by high densities of surface-deposit feeders, to the exclusion of other more pollution-intolerant species. The structure and density of this existing benthic community suggests that the site is already organically enriched. The effect of the large amounts of discharge on the benthic community is predicted to be significant. The additional nutrient levels and decreasing oxygen levels would exceed the assimilative capacity of the community and would result in major structural and functional alterations in the macrobenthos. These include major reductions in total density, species richness, diversity and eveness. Pollution-sensitive species would be greatly reduced or eliminated resulting in a shift to highly pollution-tolerant species. Major effects are likely to appear in the immediate 2.4 square mile area surrounding the diffuser, and moderate effects would extend over a much larger area (166 square miles) of Massachusetts Bay.

10.2.3 Finfish/Lobsters

The proposed ocean outfall option is expected to negatively affect local populations of finfish and lobster for a number of reasons. The anticipated changes in the benthic community are expected to have a negative impact on the finfish and lobster who feed on these benthic organisms. The resulting alterations in diversity and structure of the benthos will reduce the amount of food which is available to the finfish and lobsters (Ennis, 1973) and thus will reduce finfish and lobster population within the immediate zone of intial dilution. This effect may extend over a much larger area of Massachusetts Bay. Lobsters may be more negatively influenced than the finfish by the increased organic loading from the discharge, as was observed near another wastewater discharge north of Boston Harbor (Tetra Tech, 1981).

A slight shift in the distribution and abundance of the finfish community may also occur because of the increased amounts of organic loading. The settling of these effluent solids is predicted to alter the substrate composition of the site to one preferred by winter flounder. As a result, it is expected that the winter flounder will replace other finfish species, particularly the now-dominant yellow tail flounder.

The discharge into Massachusetts Bay will also contain toxic materials including some heavy metals and PCBs. These toxic pollutants can affect marine organisms in a number of ways. Acute exposure can lead to death, while exposure to lower concentrations can induce sublethal effects such as reduced survival of young, lowered resistance to disease and deleterious changes in behavior. These sublethal, chronic concentrations can, in turn, reduce species distribution and abundance.

The toxicity of certain heavy metals is influenced, however, by the chemical form taken by the metal. Acute, short-term effects are more likely to occur when the metals are in ionic form while chronic, long-term effects are most likely to occur when metals are complexed in organic form and are relatively non-ionic. It is in this chemical state that the metals will accumulate within body tissues and can be transferred to other organisms through the food chain.

Bioaccumulation of toxic substances is even more likely to occur with organic toxicants, such as certain types of pesticides and PCBs, because their neutrally charged organic form allow a much easier passage across cellular membranes. In addition, many of these organic compounds are very resistant to degradation. As a result, these long-lasting residues will pass through the food web, ending up in commercially and recreationally important species of fish, and will be transferred to humans when these fish are consumed.

The proposed ocean outfall option will remove about the same percentage of metals, pesticides, PCBs and other toxic materials as does the existing STP (see Table 2-3 in Section 2). This means that metals such as cadmium, chromium, copper, lead, mercury and zinc will, at most, be reduced by 40 percent from their influent concentrations. Based on data collected near the current Deer Island and Nut Island outfalls (US EPA, 1983) annual average concentrations of three metals, copper mercury and silver, were found to exceed EPA water quality criteria.[a/] It was also found that PCBs were appearing in the effluent at 19 to 320 times the EPA criterion. A study of the toxic chemical concentrations in the tissues of lobster and winter flounder near the discharges indicated that PCBs are bioaccumulating in the edible tissues of these species. It was shown, however, that the other chemicals sampled--DDT, mercury, silver, cadmium, copper and lead--were not

---

a/ (See US EPA, 1983 and 45 Fed. Reg. 79318, November 38, 1980.)

bioaccumulating in fish and lobster tissues, although this does not mean that these organisms are otherwise not being negatively influenced by concentrations in the water column.

Finally, the discharge from the ocean outfall is expected to contribute to the problem of fin erosion in demersal fish. Although the exact cause of fin erosion is not known, there is evidence to suggest that fish develop the disease when they come into constant contact with contaminated sediments, particularly those contaminated with PCBs (Sherwood, 1979; US EPA, 1983). There is evidence that current MDC discharges into Boston Harbor are contributing to fin erosion, particularly in winter flounder, and thus it is likely that the proposed discharge of effluent into Massachusetts will have a similar negative effect in local fish populations.

10.2.4 Endangered or Threatened Species

The ocean outfall option may adversely affect transient threatened or endangered species which appear in or obtain nutrients from the waters of Massachusetts Bay. The affected organisms include several species of whale, and are listed below:

Blue Whale	Balaenoptera musculus
Finback Whale	B. physalus
Sei Whale	B. borealis
Minke Whale	B. acutorostrata
Humpback Whale	Megaptera noveanglias
Right Whale	Eubalaena glacialis
Loggerhead Sea Turtle	Caretta caretta
Leatherback Sea Turtle	Dermochelys coriacea
Shortnose Sturgeon	Acipenser brevirostrum
American Peregrine Falcon	Falco peregrinus anatum

All of these species are migratory, particularly the whales who travel from the Gulf of Maine down the coast to Delaware Bay and southward to Georgia and Florida. Two endangered species, the Right and Humpback Whale, and the threatened Fin Whale are known to feed in summer along the shoreline areas of Massachusetts and Cape Cod Bay on their migration along the East coast. Their food sources include fish, krill or related crustaceans, and zooplankton, which, as discussed previously, are likely to be negatively affected by the conventional pollutants or by toxic pollutants discharged into Massachusetts Bay. Although it is impossible to quantify these effects on these species of whale and on the other species, it is likely that heavy metals and the organic toxics will have the most deleterious impacts on these endangered/threatened organisms.

References

Ennis, G.P., 1973. Food, feeding and condition of Lobsters, Homarus Americanus, throughout the seasonal cycle in Bonavista Bay, Newfoundland, Journal of Fisheries Research Board of Canada, 30:1905-1909.

Gosselink, J.G., E.P. Odum, R.M. Pope, 1973. The Value of the Tidal Marsh, Center for Wetlands Research, Louisiana State University, Baton Rouge, Louisiana.

Lynne, G.D., P. Conroy, F.J. Prochaska, 1981. Economic Valuation of Marsh Areas for Marine Production Processes, Journal of Environmental Economics and Management, Vol. 8, No. 2.

Metcalf and Eddy, September 13, 1979. Application for Modification of Secondary Treatment Requirements for Its Deer Island and Nut Island Effluent Discharges into Marine Waters, for the Metropolitan District Commission, Boston, MA.

Odum, E.P., 1961. Fundamentals of Ecology, W.B. Saunders Co.

Sherwood, M.J., 1979. The Fish Erosion Syndrome, Coastal Water Research Project Annual Report for 1978, W. Bascom (ed.) SCCWRP, El Segundo, California.

Teal, J.M., 1962. Energy Flow in the Saltmarsh Ecosystem of Georgia, Ecology 43:614.

Tetra Tech, Inc., 1980. Technical Evaluation of Deer Island and Nut Island Treatment Plants Section 301(h) Application for Modification of Secondary Treatment Requirements for Discharge into Marine Waters, Bellevue, Washington.

Tetra Tech, Inc., 1981. Technical Evaluation of Lynn Wastewater Treatment Plant Section 301(h) Application for Modification of Requirements for Discharge into Marine Waters, Bellevue, Washington.

U.S. Environmental Protection Agency, 1983. Analysis of the Section 301(h) Secondary Treatment Waiver Application for Boston Metropolitan District Commission, Office of Marine Discharge Evaluation, Washington, DC.

Welch, E.B., 1980. Ecological Effects of Wastewater, Cambridge University Press, New York, New York.

Westman, Walter E., 1977. How Much Are Nature's Services Worth, Science 2: 960-964.

Section 11
Secondary Effects

The benefits associated with the previously discussed pollution abatement options which accrue from increases in recreational activity, commercial fishing and other activities, are all primary benefits; that is, they are direct impacts of the proposed projects. Another type of benefit--secondary benefits--measures the net increase in economic activity generated by the direct impacts and indirectly attributable to the treatment alternatives. Secondary benefits are added to the primary benefits of a pollution abatement project only if there is widespread unemployment nationally or regionally and only if it is expected that these unemployed resources would be used in the economic activity thus generated. Otherwise, it can be assumed that any increased economic activity stimulated by the project would represent only a transfer of productive resources from one use to another and would not be a net benefit. The rules and procedures governing the inclusion of secondary benefits are found in Section XI 2.11 of Water Resources Council, "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" (1983).

These Principles and Guidelines state th t conceptually any employment of otherwise unemployed resources that results from a project represents a benefit but that difficulties in identification and measurement may preclude any but those labor resources employed onsite in the construction of the project be counted. For this case study, the construction options have not been sufficiently developed to categorize types of labor resources required. Instead, some of the other indirect employment categories are discussed.

Since unemployment is often cyclical, secondary benefits may not accrue to the proposed projects over the long-run unless structural unemployment (unemployment unaffected by normal cyclical upturns in the economy) is alleviated. A detailed labor market analysis is required to determine the types of unemployed resources that exist and whether the mix of skills required for the economic activity generated by the pollution abatement options would use those resources. Even in a less than full-employment economy, as is currently the case, some resources that would be employed to meet the increase in economic activity would be transferred from other productive uses either within the region or outside the region (e.g. outside Massachusetts or New England). If this were the case, these effects, although they might be very important to the region, would not represent net benefits from a national perspective (unless structural unemployment was affected, as mentioned before). This section, therefore, refers to the indirect impacts attributable to the treatment alternatives as secondary effects and presents a method for their valuation. Under certain conditions these effects may be considered benefits but the labor market analysis required for this determination is beyond the scope of this case study.

11.1 Methodology

Secondary effects can accrue to a region from increased activity in any local industry. For example, additional wages are spent on food, clothes, rent, etc. and increased business production requires additional purchases of materials used in production. These purchases stimulate increased economic activity. For every additional dollar of direct income or of total output (sales) from the industry, a certain dollar amount of associated economic activity is generated; these amounts are known as multipliers for that industry and provide a way to estimate the economic value of secondary effects. Multipliers for estimating increased economic activity in an area usually cover three kinds of effects: direct, indirect and induced. Direct effects are the changes in income to households resulting directly from the changes in output of the industries of interest. Indirect effects are additional economic activities stimulated by the direct impacts of the project, i.e., changes in activity in all industries which supply goods and services to the primary impact industries. Induced effects are those that result when consumers adjust their consumption patterns in response to changes in income. All three effects may be of interest in this case.

Two types of multipliers are used to estimate increased economic activity generated by an industry. The output multiplier is used to compute the total value of economic activity generated. Not all of this value remains in a community or region, however (and, as discussed before, much of it may represent a diversion of resources rather than a net gain). Some goods and services purchased by businesses or by employees are produced locally and others are produced outside the area. *The income multiplier measures only the portion of the economic activity generated which remains in an area as income to residents. For the purpose of measuring secondary benefits from pollution abatement options, the best measure would be the output multiplier as we are interested in national welfare rather than regional effects.

To estimate the secondary effects which would accrue to the Boston Harbor pollution abatement options, multipliers are used that have been estimated from economic input-output analyses. Input-output models represent the economy of an area and the transactions which occur among industries located there. From such a model it is possible to estimate the effects of a change in one industry on all the other industries. The advantage of input-output analysis over other methods of estimating multipliers is that it provides both comprehensive and detailed coverage of the industries of interest.[a/] The disadvantage of this and other methods is that only gross changes are estimated; net effects exclusive of transfers of resources are not measured.

11.2 Benefit Estimates

The multipliers used to estimate secondary effects should correspond to the type of data available on the impact of the pollution abatement options. In this case, it is easier to estimate the impact on the output (sales) of an of an affected industry (such as shellfishing or boating) than to estimate the impact on direct income (wages). Thus, the multipliers shown in Table 11-1 estimate the total direct, indirect and induced effects of a one dollar change in the sales of each impacted industry.[b/]

A range of multipliers has been included in Table 11-1. The multipliers for the shellfishing and related industries come from three studies, one of Cape Cod, one of the Southern New England Marine Region (SNEMR), including Rhode Island, Cape Cod and parts of Southeastern Massachusetts and Connecticut, and one of the State of Maine (Cape Cod Planning and Economic

---

a/ Other types of multipliers have been developed. For example, E. Wong (1969) has estimated a multiplier for shellfish which computes the value added by harvesters, wholesalers and retailers both inside and outside the community. This kind of multiplier would not capture the indirect or induced effects of the shellfish industry the way an input-output derived multiplier would.

b/ They could be converted for use with direct income impact data by dividing by factors which show the effect on direct income of a one dollar change in output for each industry.

Table 11-1

Multipliers Showing Direct, Indirect and Induced Effects
Per $1 Change in Output

Industry	Cape Cod Study Income Multipliers	Cape Cod Study Output Multipliers	SNEMR Study Income Multipliers	Wisconsin Study Output Multipliers	Maine Study Income Multipliers
Commercial Shellfishing	1.1749	3.0010	1.1441	-	1.54
Fish Processing	-	-	.7027	-	
Clam and Worm Processing	-	-	-	-	1.65
Shellfish Whole-saling	1.0772	3.6444	-	-	-
Seafood, Whole-saling and retail	-	-	.7781	-	-
Eating and Drinking Establishments	.5158	2.0179	.7997	2.2705	-
Marinas and Boatyards	.6829	2.4971	.7037	-	-
Charter Sport-fishing	.9038	2.8200	.7982	-	-
Tourist[a]	-	-	-	2.1741	-

a/ Weighted average of impacts of tourist expenditures on all industries.

Sources: Briggs, Townsend and Wilson, 1982; Cape Cod Planning and Economic Development Commission, 1978; Grigalunas and Ascari, 1982; Strang, 1971.

Development Commission, 1978, Grigalunas and Ascari, 1982, and Briggs et al., 1982).[a]

Both output and income multipliers are available from the Cape Cod study while only income multipliers are available from the SNEMR and Maine studies. As can be seen from the table, the Cape Cod output multipliers are about three times greater than the income multipliers for the same study. Although it was not possible to calculate output multipliers for the SNEMR or Maine studies because of lack of data, the difference between income and output multipliers would be less for these studies than for the Cape Cod study. The reason for this is that both the State of Maine and the SNEMR region are larger and more self-sufficient and would therefore retain more earnings and import fewer goods and services.

There were no input-output analyses available for marine activities in the Boston area. Since the structure of harvesters, wholesalers and retailers of soft shelled clams in the Boston area is probably similar to those of Maine, Cape Cod and the SNEMR, the multipliers presented in Table 11-1 can be used to provide a range of secondary effects estimates for the pollution abatement options as shown in Table 11-2.

Although, as mentioned earlier, income multipliers measure only income remaining in an area and, therefore, understate the total national welfare impacts of the pollution abatement options, they are included as part of the range in Table 11-2 for two reasons. First, Boston area output multipliers

---

[a] Multipliers from two other input-output analyses, an earlier SNEMR study and a Rhode Island study, were presented in Grigalunas and Ascari. Unfortunately, they were of the form that is multiplied by direct income rather than by sales, and data were not available to convert them to the form useable here. In the form that they were available, however, these multipliers fell between the Cape Cod and SNEMR figures, and so would probably lie within the range shown in Table 11-1.

Table 11-2. Secondary Effects Estimates
(Thousands $1982)

Industry	Estimated Change in Sales for Each Pollution Abatement Option (Thousands 1982$)				Multiplier Range ($)	Secondary Effects Range for Each Pollution Abatement Option (Thousands 1982$)			
	CSO			STP		CSO			STP
	Constitution	Dorchester, Neponset	Quincy	Ocean Outfall or Secondary		Constitution	Neponset/ Dorchester	Quincy	Ocean Outfall or Secondary
Commercial Shellfishing									
Harvesting	94.2	149.2	72.1	885.6	1.14-3.00	107.4- 282.6	170.1- 447.6	82.2-226.3	1,009.6- 2,656.8
Distribution and Processing a/	74.0	117.2	56.7	695.8	0.70-3.64	51.8- 269.4	82.0- 426.6	39.7-206.4	487.1- 2,532.7
Restaurants a/	104.3	165.2	79.8	980.3	0.80-2.02	83.4- 210.7	132.2- 333.7	63.8-161.2	784.2- 1,980.2
Subtotal	272.5	431.6	208.6	2,561.7	-	242.6- 762.7	384.3-1207.9	353.8-583.9	2,280.9- 7,169.7
Recreation									
Swimming b/	103.3	704.7	540.1	111.6	0.80-2.27	82.6- 234.5	563.8-1,600	432.1- 1,226.0	89.2-253.3
Other b/				201.6					161.3-457.6
Boating c/	538.6-1,457				0.70-2.50	377.0-3642.5			
Fishing c/	29.9-949.3				0.80-2.82	23.9-2,677			
Subtotal d/	103.3	704.7	540.1	313.2	-	82.6-234.5	563.8-1,600	432.1- 1,226.0	250.5- 710.9
TOTAL d/	375.8	1,136.3	855.6	2,874.9	-	352.2-997.2	948.1- 2,807.9	785.9- 1,809.9	2,531.4- 7,880.6

a/ Sales per bushel for Distribution and Processing and Restaurants assumed to maintain the same relation to harvest sales per bushel for Boston Harbor as for Resources for Cape Ann study.

b/ $1 per visitor-day assumed spent on food and beverages. Visitor days are average of upper and lower bounds for swimming from Table 6-6 and for "other" from Table 6-12.

c/ Ten percent of boating and fishing benefits (see Section 6) assumed as sales for marinas and boatyards and for charter sportfishing, respectively. Based on Table 6-10 (boating) and 6-11 (fishing).

d/ Not including fishing and boating sales and secondary effects.

would probably be closer to Boston area income multipliers for the same reasons as mentioned above for Maine and the SNEMR. Second, as discussed above, even in a less than full-employment economy, some resources that would be employed to meet the increases in economic activity generated by the pollution abatement options would be transferred from other productive uses and thus would not represent net benefits. A multiplier which underestimates secondary effects is therefore appropriate.

Besides secondary effects generated from increased shellfish harvesting, a certain level of economic activity may also be stimulated in the distribution and processing and restaurant sectors for each additional bushel harvested. To estimate these effects it was assumed that the level of sales generated in the distribution and processing and restaurant industries as compared to the harvesting industry would be the same for Boston Harbor as for the Cape Ann area (see Resources for Cape Ann, 1982) and that this relationship would be maintained across price changes.[a/][b/] Since Boston is a major market area for shellfish, this is a conservative assumption. Secondary effects can therefore be estimated for these two industries as well as for harvesting.

Recreation multipliers in Table 11-1 come from the Cape Cod and SNEMR studies and, for comparison purposes, from a study done for a county in Wisconsin which has a significant tourist industry (Strang, 1971). This study was included because there is no data available on sales generated by swimmers

---

a/ Thus, at a price of $31.41 to the digger, for example, each bushel of clams harvested would generate $90.86 of sales (total sales divided by number of bushels harvested). Of this, $31.41 would be harvesting sales, $24.68 distribution and processing sales, and $34.77 restaurant sales. These per bushel sales figures are multiplied by the increased harvest to estimate the changes in sales shown in Table 11-2.

b/ The $31.41 per bushel harvest price and the other per bushel sales figures given in footnote a/ are prices for 1980 from Resources for Cape Ann, 1982, updated to 1982 prices using the soft shelled clams price index from National Marine Fisheries Service, NOAA, 1982.

at Boston area beaches, while data from the study includes tourist receipts in the input-output analysis. This study also developed a "tourist multiplier" which is a weighted average of the impacts of tourist expenditures on all industries.

The multipliers for Eating and Drinking Establishments, Marinas and Boatyards and Charter Sportfishing from Table 11-1 were used to develop a range of multiplers to estimate recreation secondary effects for the Boston Harbor pollution abatement options, as shown in Table 11-2. The same considerations discussed above for the shellfish multipliers, concerning the inclusion of income multipliers and the assumption of comparability of multipliers across study areas, hold for the recreation multipliers.

In order to compute secondary effects for recreation activity associated with the pollution abatement options, a judgment was made that a maximum of ten percent of boating sales could be applied to marinas and boatyards and that ten percent of fishing sales could be applied to charter fishing. Boating and fishing sales data come from Tables 6-10 and 6-11. Since there were no data on expenditures by swimmers, it was assumed that one dollar would be spent for each person-day and that it would most likely be spent for food or beverages. Swimming visitor day data come from Table 6-6. Thus, the Eating and Drinking Establishments multipliers from Table 11-1 were used to develop a multiplier range in Table 11-2.

Table 11-3 compares multipliers which measure only indirect and induced effects with those that also include direct income effects. These data were only available for the SNEMR study, not for the Cape Cod study. It could be

Table 11-3.

Comparison of Multipliers With and Without Direct Effects per $1 Change in Output

Industry	SNEMR Study Income Multipliers		Indirect and Induced Effects as a Percentage of of Total Effects a/
	Direct, Indirect and Induced Effects	Indirect and Induced Effects	
Commercial Shellfishing	1.1441	.4754	42
Fish Processing	.7027	.5725	81
Seafood, Wholesale and Retail	.7781	.6876	88
Eating and Drinking Establishments	.7997	.4518	56
Marinas and Boatyards	.7037	.3847	55
Charter Sport-fishing	.7982	.4321	54

a/ (Column 2 divided by column 1) x 100.

Source: Grigalunas and Ascari, 1982.

argued that secondary effects should not include direct income effects. If this were the case, then the shellfish harvesting secondary effects estimates shown in Table 11-2 would be reduced by about 60 percent, the related shellfish industries by approximately 20 percent and the recreation activities by around 50 percent. However, it does not appear that the direct income effects would be double counting either the willingness to pay for improved recreation experiences or the changes in producer or consumer surplus due to increased shellfish harvest.

In evaluating the range of secondary effects estimated in Table 11-2, and in addressing the question of whether and how much of the secondary effects should be added to the primary benefits to derive the total benefits associated with each pollution abatement option, the important consideration is the level and type of unemployed resources assumed. If there is widespread, long-term unemployment, then the full amount of the secondary effects could be counted and the upper bounds in Table 11-2 used. If there is a full employment economy, then secondary benefits would be either zero or the difference between the value that the resources currently earn compared to what they would earn if they were employed in activities stimulated by the abatement option, if these values are different. As mentioned above, the kind of detailed labor market analysis that would be required to estimate this difference is beyond the scope of this study. If some unemployment exists as is the present situation and if a labor market analysis showed that it was likely to be long-term and composed of the skill levels required by the economic activity generated, then the lower bounds in Table 11-2 may be the best estimates to use and would represent a moderate benefit level.

11.3 Limits of Analysis

The major problem in carrying out this analysis is determining whether the secondary effects that can be estimated should be counted as benefits and added to the primary benefits of the pollution abatement options. The data are lacking to estimate the degree to which resources required for the increased economic activity generated by the pollution abatement options would be otherwise productively employed in the long run. Since we are interested in estimating net benefits, transfers of resources already occupied to activity stimulated by the pollution abatement options should not be counted. Even given high unemployment as is the case in the current recession, it is difficult to appropriately handle this problem.

Another limitation of this analysis of secondary effects is the lack of an input-output model of marine related activities for the Boston area. A related problem was the lack of data to compute output multipliers for the SNEMR. The availability of these data would have produced a better range of estimates of secondary effects.

References

Briggs, Hugh, Ralph Townsend and James Wilson, January 1982. An Input-Output Analysis of Marine Fisheries in Marine Fisheries Review, Vol. 44, No. 1.

Cape Cod Planning and Economic Development Commission, 1978. An Economic Profile of the Cape and Islands Fisheries, Barnstable, Massachusetts.

Grigalunas, Thomas A. and Craig A. Ascari, Spring 1982. Estimation of Income and Employment Multipliers for Marine-Related Activity in the Southern New England Marine Region, Journal of the Northeastern Agricultural Economics Council, Vol. XI, No. 1, pp. 25-34.

Resources for Cape Ann, April 1982. The Costs of Pollution: The Shellfish Industry and the Effects of Coastal Water Pollution, Massachusetts Audubon Society.

Strang, William A., 1971. Recreation and the Local Economy: Implications for Economic and Resource Planning, Marine Technology Society, Washington, D.C.

U.S. EPA, 1982. Benefit-Cost Assessment Handbook for Water Quality Programs, Draft, Economic Analysis Division, Washington, D.C.

U.S. Water Resources Council, December 14, 1979. NED Benefit Evaluation Procedure: Unemployed or Underemployed Labor Resources, Section 713.1201 of Procedures for Evaluation of National Economic Development Benefits and Costs in Water Resources Planning (44 FR 72892).

Wong, Edward F.M., October 1969. A Multiplier for Computing the Value of Shellfish, U.S. Department of the Interior, Federal Water Pollution Control Administration, Needham, Massachusetts.

Section 12
Charles River Basin Benefits

The Charles River Basin has been designated by the MDC as one of the four CSO planning areas. The Charles River Basin includes the Back Bay Fens, the Muddy River, Alewife Brook and the Charles River itself. The basin is mixed fresh and salt water and is used primarily for non-contact recreation, both on the water and at the water's edge. There is little or no fishing in the Charles River Basin. The Charles River is the major water resource in the Charles River Basin and draws the greatest number of recreators. For this reason, as well as data limitations, we have chosen to estimate benefits only for the Charles River.

12.1 The Charles River

The Charles River is 80 miles long, with a watershed of 300 square miles. The portion of the Charles that is contained in the Charles River Basin CSO planning area runs from the Watertown Dam to the Charles River Dam near the mouth of Boston Harbor (see Figure 12-1). This section of the River has an average annual level of 2.38 feet, and contains approximately 675 surface acres of water. The length of the River within this stretch is 8.6 miles. The Charles River is an important water-based recreation resource, especially to the towns through which it flows. Although there is currently little swimming in the river (and none predicted with the proposed CSO plans), the river plays host to a variety of boaters. Sailing and motorboating are extremely popular, especially at the wider portions of the river, near the Harbor. There is also a significant number of people who

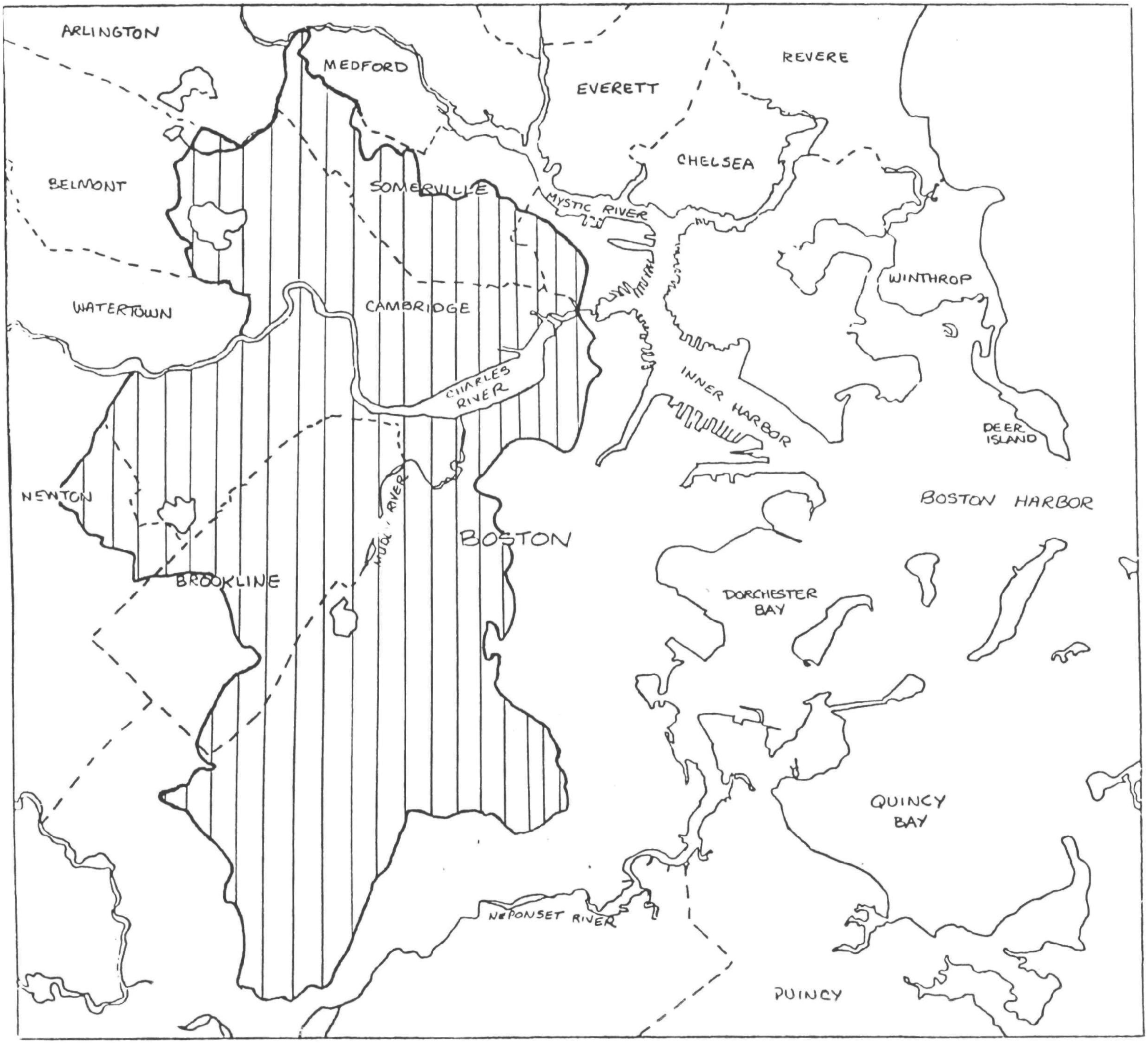


Figure 12-1. Map of Charles River Basin

Charles River Basin Planning Area

scull on the Charles. Every major college and university in the Boston area has a boat house along the river; their crew members practice almost daily during the spring and fall months. The river is also an aesthetic focal point for other recreation-based activities. An MDC bikeway follows the course of the river and doubles as a running path. Picnickers, sunbathers, and strollers also take advantage of the open space provided by the river. Major cultural events such as crew regattas, formal and informal concerts, and city festivals take place along the river's edge and attract thousands of residents and sight-seers.

The Charles River violates the state water quality standards. Those standards (a rating of "C") allow non-contact recreational use. The river is polluted with extremely high levels of coliform counts, odors, floatables, debris, and turbidity. The recommended CSO plan (see Section 3.5) includes capturing, transporting, and storing overflow from the CSOs and is predicted to result in 50 to 80 percent removal of suspended and floatable solids, coliforms and BOD_5. Water quality will improve greatly although swimming will still not be permitted.

It is difficult to quantify the instream and near-stream user benefits to be gained from improving the water quality in the Charles because of data and methodological limitations. Unlike swimming benefits, there are no good travel models or data available to predict how user participation and utility will increase. There are also few intrinsic value studies which are applicable to the Charles River area. We have chosen two techniques and two studies to evaluate user and non-user benefits from abating pollution along the Charles River. User benefits to boaters are estimated using a boating participation model developed by Davidson et al. (1966) while both intrinsic and user benefits are developed by applying results from a contingent valuation survey (RTI, 1983).

12.2 Boating

The effect of water quality on the level of recreational boating has been studied. The results of the Davidson et al. study (1966) show that the number of participants within a given population as well as the number of days of boating participation per year show significant increases with improvement in the quantity and quality of available waters. Davidson's approach to estimating boating-related benefits includes calculating (a) the change in the probability of boating participation among the general population as a result of improvement in water quality and availability and (b) the change in number of days of participation per year. The Davidson model attributes most of the benefits of water quality improvement to new participants. It does not capture any benefits accruing to current boaters. The Davidson model estimated, in a study of the Delaware Estuary, that each increase in recreational boating water of one acre per capita resulted in a 38 percent increase in participa- tion rates (i.e., the probability of an individual participating in boating increased by 38 percent). The portion of the function describing boating participation, which is applicable to this study, can be expressed in the following reduced form:

$$BP = 0.38485(\Delta W) + 0.03142(\Delta FPS)$$

where: BP is the probability of boating participation
W is the per capita acreage of recreational water available
FPS is the recreational facility rating.

The FPS variable represents an index of the quality of boating facilities. A rating of "1" implies "no facilities," while a rating of "5" suggests "very good facilities."[a/] Socioeconomic variables were included in the regression, including education, income, occupation, age, and race, but were not well correlated with boating participation. Davidson et al. also assumed that elimination of pollution discharges into the Delaware Estuary would produce a minimal one point improvement (from 2.0 to 3.0) in the FPS rating.

12.2.1 Methodology

It is possible to apply this model to the Charles River. Estimation of boating-related benefits involves the following steps:

a. Estimate the increase in recreational boating water and boating facilities from improving water quality in the Charles River as a result of implementation of the CSO plan;

b. Estimate the change in the probability of boating participation in the general population as a result of improvement in water quality and availability of boating facilities;

c. Estimate change in total participation attributable to water quality improvements;

d. Estimate the value of the additional boating days.

The first step involves estimating the increase in recreation boating water (ΔW) and facilities (ΔFPS) as a result of improving water quality. Although ΔW is the key explanatory variable in the Davidson equation,

---

[a/] Davidson et al. used fishing facilities rather than boating facilities because the former were not available for their sample area.

the value of the variable is quite small for the Charles River. The Charles River has only 675 acres of water available for boating of all kinds. Although the Charles is polluted, there appear to be few portions of the river which are unboatable because of pollution. Therefore, the change in acreage of recreational water available per capita following water quality improvements is essentially zero. Although this assumption of zero change in water acreage might appear to be too conservative, even if we were to assume that all 675 acres of the river were previously unboatable, a ΔW of 675 acres would only lead to a very small per capita acreage increase of from 0.0317 to 0.0318.[a] It is, therefore, apparent that the variable FPS will have the greatest effect on predicting the change in boating participation. Davidson *et al*. assumed that eliminating pollutant discharges into the Delaware estuary would produce a minimal one point improvement in the recreational facilities from a rating of "2" to a rating of "3." The same assumption was used for the Charles River, that ΔFPS is 1.

Calculating the total additional boating days requires information on current boating use of the Charles River. As described in the swimming section, recreation statistics on attendance and days per participant are not officially recorded by the MDC. We have, therefore, used a number of sources to estimate a range of boating participation on the Charles. Information from a study by Binkley and Hanemann (1975) indicates that 850 visits were made to two sites along the Charles River during the summer season, and that 5.6 percent of the visits were boating-related. Results from the study

---

[a] Depending on a range of 183,000 - 1,680,800, boating participants as described in Appendix E.

suggest that it is correct to assume that the survey sample was statistically representative of the entire Boston SMSA. These 850 survey visits can be extrapolated into 68,000 family visitor days and approximately 183,000 visitor days (see Appendix E). This is probably an understated estimate because only two sections of the entire length of the Charles River were sampled.

An alternative method is to apply the approach used in the previously-described swimming section which is based on regional recreation studies. This method assumes that (1) 40 percent of the population goes boating, (2) a user population of 764,000 (see Appendix E for details), and (3) users go boating an average of 5.5 days per year. The resulting boating days are 1,680,800. The Binkley-based estimate of 183,000 vistor days is used as a lower bound, and the recreation study-based estimate of 1,680,800 is used as an upper bound. The lower bound estimate appears to be the more reasonable.

Additional boating days can be estimated multiplying the previously derived ΔW and ΔFPS value by the estimated number of general population boaters (see Appendix E for details). The increase in visitor days ranges from 5,750 to 52,810.

12.2.2 Benefit Estimates

Boating benefits from improved water quality resulting from implementation of CSO plans can be estimated by valuing the increase in visitor days developed and described above. The range of user day values that have been developed for boating are presented in Appendix B (Table B-1)[a]. By applying this range of values ($9.27-$18.14) to the projected increase in boating days, we can arrive at an estimate of boating benefits, presented in Table 12-1.

Table 12-1. Annual Recreational Boating Benefits

(1982$) $/Boating Day	Number of Additional Boating Days	Total Annual Boating Benefits (Thousands 1982$)
High 18.14	52,810	958
Low 9.27	5,750	53

Boating-related benefits from improving water quality on the Charles River are modest because the estimated increase in number of boating days is small and because boating day values which are applicable to this study represent the lower, rather than upper, end of the range of user-day values.

12.2.3 Limits of Analysis

Calculation of boating-related benefits is limited by the methodology employed, the data base, and the numerous assumptions made. The application of the Davidson *et al.* boating model may lead to biased benefit estimates. First, the model only measures benefits which accrue to new participants and does not capture benefits of increased participation or increase in utility

---

[a] We have chosen not to use the boating value of $45.19 derived from the NPA in conjunction with Charbonneau and Hay because we believe that it overstates the particular value of boating on the Charles River. This is because the greater portion of boaters who use the river do so in small-powered craft (such as sculling shells, kayaks, small sailboats, canoes, and low horsepower motor boats), rather than large-powered craft.

to existing users. Second, the model may not, for a number of reasons, be easily applied to an urban area. The key explanatory variable in the model is the supply of boatable water that is expected to increase following water quality improvement. In the case of the Charles River, the value of this variable is extremely small because virtually all 675 acres of river are currently used for boating. Even assuming that all acres were previously unboatable, the increase of 675 acres would only lead to an increase of 0.0317 acres per capita and, therefore, would account for only an 0.012 change in boating participation. The second variable in the model--change in recreational facility rating--then becomes the key explanatory variable of the increase in boating participation. There are few places along the urbanized riverfront of the Charles available for development or expansion of marinas and, thus, we have assumed that the one point change in facility rating reflects the improvement in boating facilities. This assumption, however, is difficult to verify.

Other problems with estimating boating benefits from CSO pollution control plans along the Charles lie in the available recreational data. There is scant information about days of boating participation along the Charles and the percentage of the entire population in the Boston Metropolitan area who boat there. The use of user-day values is also likely to bias the benefits estimates. The lower range of available user day boating values ($9-$18/day) was used to calculate benefits because of the nature of boating (in non-motorized and small-powered craft) on the river.

12.3 Intrinsic (Non-User) and User Benefits

An alternative method for computing the benefits from CSO pollution control plans on the Charles River is to apply the results of a contingent valuation survey, which captures the amount users and non-users are willing to pay for improved water quality. As mentioned previously, the Charles River is a major aesthetic focal point for recreation-based activities. It is difficult to estimate the exact number of people who are not direct users of the River but who, instead, ride, picnic, run, or stroll along the Charles' shores. It is safe to assume, however, that there are probably few families or individuals in the towns through which the river runs who have not enjoyed the river at least once. Calculating benefits which accrue to these "non-users" is a necessary part of developing total benefits.[a]

We have chosen the results of a contingent valuation survey described in detail in RTI (1983) to capture instream, near-stream and intrinsic benefits from improving water quality through upgrading CSO's in the Charles River Basin area. A study conducted by Gramlich (1974) to determine the willingness to pay for improving water quality in the entire 80 mile length of the Charles River was not considered applicable here, because the survey only recorded results for willingness to pay for obtaining a swimmable level of water quality (classification "B"). The CSO plans and their costs have been developed only for improving the river to a level "C," or boatable use. Also, the results from the Gramlich study cannot be disaggregated by user and non-user.

---

[a] For a discussion of non-user (Intrinsic) values and estimation methodology, see Section 9.

12.3.1 Benefit Methodology and Estimates

Estimates of willingness to pay for improving Charles River water quality can be derived by applying the results of a study conducted by RTI, along the Monongahela River in Western Pennsylvania. The RTI study used a contingent valuation approach to measure willingness to pay for improved water quality. Results from the RTI study suggest that user and non-user households are willing to pay $18.68 (1982$) for water to go from boatable to fishable conditions.[a/] In order to calculate total benefits, it is necessary to multiply this dollar WTP value per household times the regional household population.

For the Charles River area, an upper bound was established by including residents of towns bordering or very close to the Charles River: Cambridge (95,000), Somerville (77,000), Watertown (34,000), Newton (83,000), Brookline (55,000), Boston (560,0000) or a total of 905,000.[b/] Assuming an average household size of 2.69,[b/] an upper bound household population figure is calculated to be 336,000. A lower bound can be developed by assuming that only one half the populations of these towns benefit from CSO-based water quality improvements, or 452,000 people, which translates to a lower bound of 168,000 households. Multiplying the RTI-derived WTP values of $18.68 by the range of applicable households results in significant benefits, presented in Table 12-2.

---

a/ This is based on a direct question framework, users and non-users. See page 4-32, RTI, 1983.

b/ Based on data from 1980 Census.

Table 12-2. Annual Estimated Willingness to Pay for Fishable Charles River (1982$)

	Population	Persons per Household	Willingness to Pay Value	Annual Willingness to Pay Value
High	905,000	2.69	18.68	6.28 million
Low	452,000	2.69	18.68	3.14 million

12.3.2 Limits of Analysis

Benefits to instream users, near-stream users and non-users of the Charles River are substantial. These results should be interpreted wih caution, however, for a number of reasons. The accuracy of benefit values is constrained by use of off-the-shelf models. The willingness to pay values used here are derived from a study area which may be sociologically, economically and educationally different from the population within the Charles River Basin planning area. People in the northeast, for example, recreate more often than those in the central regions of the east (1979 Survey of Recreation). The Charles River population is also more highly educated and has higher income on average than that in the Monongahela study area. The geographical nature of the two areas is also different. The Monongahela River, and the region surrounding it, are larger and much more rural than the Charles River and its study area. The urban setting of the Charles, the relative scarcity of other closeby recreational rivers, and the previously mentioned socio-economic differences suggest that the Charles River population in Cambridge and other towns might be willing to pay a higher price for river cleanup. Benefits are also understated because consumer surplus was estimated only for the Charles River portion of the Charles River Basin CSO plan; the methodology therefore does not capture benefits accruing to recreationists in the Back Back Fens, the Muddy River or Alewife Brook. The upper bound figure of $6.3 million is probably the more reliable estimate of total benefits.

12.4 Summary

The benefits of improving the water in the Charles River in the CSO Charles River Basin Planning Area are many. Benefits accrue to instream users (boaters) and near-stream users (picnickers, strollers, bikers, etc.) alike. Best annual boating benefit estimates total $958,000 and probably understate all boating benefits. Results from a contingent valuation survey capture both user and non-user benefits by applying willingness to pay values derived from a study of the Monongahela River. The upper value of $6.3 million is probably the more reliable estimate of total benefits from improving water in the Charles River, although this figure may also understate all benefits.

References

Binkley, C. and W. Hanemann, 1975. The Recreation Benefits of Water Quality Improvement. U.S. Environmental Protection Agency, NTIS PB 257719.

Charbonneau, J. and J. Hay, 1978. Determinants and Economic Values of Hunting and Fishing. Paper presented at the 43rd North American Wildlife and Natural Resources Conference, Phoenix, Arizona, Washington, D.C.

Davidson, P., G. Adams, and J. Seneca, 1966. The Social Value of Water Recreational Facilities from an Improvement in Water Quality: the Delaware Estuary. Water Research, Allen Kneese and Stephen C. Smith, eds. Baltimore: Johns Hopkins University Press for Resources for the Future.

Gramlich, F.W., 1977. The Demand for Clean Water: the Case of the Charles River. National Tax Journal 30:183-184.

National Planning Association, 1975. Water-Related Recreation Benefits Resulting from Public Law 92-500, three volumes, Washington, D.C. National Committee on Water Quality.

Research Triangle Institute, 1983. A Comparison of Alternative Approaches for Estimating Recreation and Related Benefits of Water Quality Improvements, Research Triangle Park, North Carolina.

United States Department of Commerce, Bureau of the Census, 1982. 1980 Census of Population and Housing, Masachusetts, USGPO, Washington, D.C.

U.S. Department of the Interior, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, 1982. 1980 National Survey of Fishing, Hunting and Wildlife Associated Recreation. USGPO, Washington, D.C.

U.S. Department of the Interior and Heritage Conservation and Recreation Service, 1979. The Third Nationwide Outdoor Recreation Plan, USGPO, Washington, DC.

APPENDICES

Appendix A

Correlating STP Performance and Operation to Boston Harbor Water Quality

One of the tasks <u>en route</u> to a cost-benefit analysis is to design and cost the technical options capable of modifying, maintaining, or raising the quality of the environment in question. The complement to this task is to collect data on the biological, physical, and chemical parameters of the current environment so that the changes to the environment made possible by the different technical options can be quantified. Neither of these tasks was performed by Meta Systems. Instead, technical and environmental data were collected from existing sources; no new information research (i.e., engineering analysis or environmental monitoring) was undertaken.

Correlating STP operations and performance with the water quality of the harbor is a complicated task. The problem is not so much that the necessary data does not exist at all but rather that the available information may not be collected in forms or manners suited to particular analysis goals. Water quality data shortcomings are the result of less than optimal sampling procedures such as:

- infrequent monitoring;
- parameter selections not consistent from one sampling to next;
- same locations not repeatedly sampled; and
- sampling not co-ordinated with seasonal, weather-related, tidal, STP, etc. events.

In the available reports the performance information presented for STP options differs from that presented for CSO options. The performance of the STPs under the various options is measured in terms, of effluent constituent concentrations. CSO plans, on the other hand, estimate the water qualities achievable under various CSO designs as well as reduced loadings. In order to establish potential water qualities achievable under the different STP options it was necessary to describe the dispersion of STP effluents throughout the harbor.

A.1 Influent, Effluent, and Sludge Characteristics

Periodically, the MDC takes samples of STP influent and effluent and conducts tests to determine the composition of raw and treated municipal wastewaters. (See Table A-1.) Using the concentration information from this testing, along with values for total flow volume, the pollutant loadings to the harbor due to the Deer and Nut Islands' STP options, have been calculated. The combined loadings are presented in Section 2, Table 2-1. The knowledge of influent composition enables calculation of the loadings from raw sewage discharges due to STP bypasses.

To calculate annual loadings from influent and effluent concentrations and flow volume data:

1) milligrams per liter was converted to pounds per gallon using $(8.4 \times 10^{-6})(\text{mg/l}) = \text{lbs/gal}$

2) the combined effluent discharge volume of Deer and Nut Islands was assumed equal to 500 million gallons per day (350 and 150 mgd, respectively)

3) concentrations for the individual STPs were weighted by volume of flow for a combined average concentration equal to (0.3) x (conc. at Nut Island) + (0.7) x (conc. at Deer Island)

4) annual loading: (365 days) x (500 mgd) x (combined average concentration)

Bypass loadings were calculated from:

1) influent (i.e., raw wastewater) composition; use of this data probably results in an overstatement of pollutant loadings

Table A-1.

MDC Treatment Facilities Current Pollutant

Removals for Wastewater Effluents

Pollutant	NUT ISLAND Influent (mg/l)	Effluent (mg/l)	Removal (Percent)	DEER ISLAND Influent (mg/l)	Effluent (mg/l)	Removal (Percent)
BOD_5	136.6	97.0	29.0	150.0	108.0	28.0
TSS	178.3	82.0	54.0	155.5	70.0	55.0
Cadmium	0.0176	0.0119	32.4	0.021	0.019	9.5
Chromium	0.051	0.041	19.6	0.147	0.108	26.5
Copper	0.618	0.292	52.8	0.246	0.357	-45.1 a/
Lead	0.104	0.074	28.8	0.157	0.131	16.6
Mercury	0.00199	0.00120	39.7	0.00124	0.0011	11.3
Nickel	0.889	0.291	67.3	0.115	0.131	-13.9 a/
Zinc	0.431	0.376	12.8	0.777	0.488	37.2

Source: The BOD_5 and TSS values are from Metcalf and Eddy, June 1982. The toxic metals data are from US EPA (1983) Table 3.2-6 and are for the period December 1975 through September 1977.

a/ The negative value of this removal percentage may be due to 1) random sampling error or 2) a propensity of the Deer Island's treatment process to concentrate this metal in the effluent rather than in the sludge.

since bypasses are often associated with storm events, thereby diluting the raw wastewater.

2) bypass volume estimates:

- for Nut Island:[a]
  Recorded untreated discharges to Boston Harbor
  January-August, 1982--2.1 billion gallons over 50 days (0.042 billion gallons/day);

  Spills of unknown amounts January-August, 1982--4 spills over 8 days estimated at 0.34 billion gallons (8.0 x 0.042);

  Total for January-August, 1982 = 2.44 billion gallons (0.305 billion gallons/month);

  Estimated annual loading = 3.66 billion gallons.

- for Deer Island:[a]

  Recorded untreated discharges to Boston Harbor
  January-October, 1982--2.2 billion gallons (0.22 billion gallons/month);

  No spills of unknown amounts;

  Estimated annual loading = 2.64 billion gallons.

- for Moon Island:[b]

  Estimated annual loading = .258 billion gallons.

Heavy metal loadings to the harbor from STP sludges were available from the draft report by Environmental Research and Technology (1978).

A.2 Pollutant Transport from STP Outfalls

To assess the impact of STP discharges in Boston Harbor, it is important to know how STP discharges are dispersed throughout the Harbor. Since discharges to the Harbor are subject to diverse and variable conditions, the water quality throughout the harbor is not uniform. Variations in quality

---

[a] Calculations based on bypass data from Dumanowski (1982).

[b] Moore (1980).

may be attributed to bottom topography, currents (directions and magnitudes), wind, and the location and means by which pollutants enter the Harbor. STP discharge dispersion is not easily correlated with the water quality of the Harbor. In order to understand the environmental consequences of STP discharges, information is needed about:

- o transport of STP loadings via water movements (current speeds, volumes of flow, flow patterns, etc.);
- o physical and chemical interactions of STP effluent and sludge with the Harbor's waters (decay rates, settling rates, chemical reactions which might neutralize toxics, chemical recombinations, how pollutants get cycled through the aquatic environment, rates of stabilization).
- o biological aspects of loadings (tolerance of aquatic organisms to loadings, pollutant uptake by aquatic organisms).

One form of water quality information available for Boston Harbor can be called "static data," which refers to measurements of ambient water quality at a specific time and location. Water quality information which describes changes in quality over time and the interactions between various elements of the harbor (physical, chemical, biological) contributes to a dynamic understanding of the Harbor's water quality. The problems with the static data available for Boston Harbor could be alleviated with more regular, extensive data collection and water quality measurement procedures. For dynamic information, however, the complexity of the harbor environment makes it extremely difficult to understand all interactions and interrelationships among its elements.

Static measurements ("grab samples") of pollutant parameters represent the contemporary environmental status of the harbor but do not clearly reflect the impacts of STP discharges in particular. Not all of the pollutant deposits in the Harbor are from the Deer and Nut Island's STPs.

Tests of harbor waters and sediments cannot distinguish among pollutants whose source is STP discharges, those deposited prior to STP operations, or those that were overflowed from a combined sewer. Not enough data has been collected to make definitive conclusions regarding discharges and their ultimate destinations. Such conclusions require a more rigorous sampling endeavor (periodic sampling, extensive coverage of harbor) and that water quality sampling be scheduled in conjunction with sampling of STP and CSO effluent to the harbor in order to correlate variations in discharges with variations in measured qualities throughout the Harbor.

Without historical information to demonstrate dispersion phenomenon of STP discharges within Boston Harbor, a predictive model of dispersion dynamics is of interest to this case study because it can help to describe what the future impacts of a number of STP options might be. Models of dispersion dynamics are perhaps the best means of determining what will happen to the effluent once it is discharged from an STP since available empirical information is insufficient for this task. A few models have been developed to quantitatively explain some aspect of the Harbor which, due to physical or economic constraints, cannot be adequately analyzed with static measurements. One model designed specifically to quantify the dispersion of STP discharges into Boston Harbor is the DISPER model, developed at MIT. It largely relies on water movement (currents) info mation to describe dispersion. DISPER itself is based on CAFE, another MIT-developed program which models these water movements. DISPER has several positive qualities which suggest that it be used as a reference. Most important is that it was designed specially for Boston Harbor. Its output also seems to correlate with the relative pollution concentrations measured throughout the Harbor. However, this may only mean that the developers of the model fit it to the existing situation, and thus it is descriptive but not necessarily predictive.

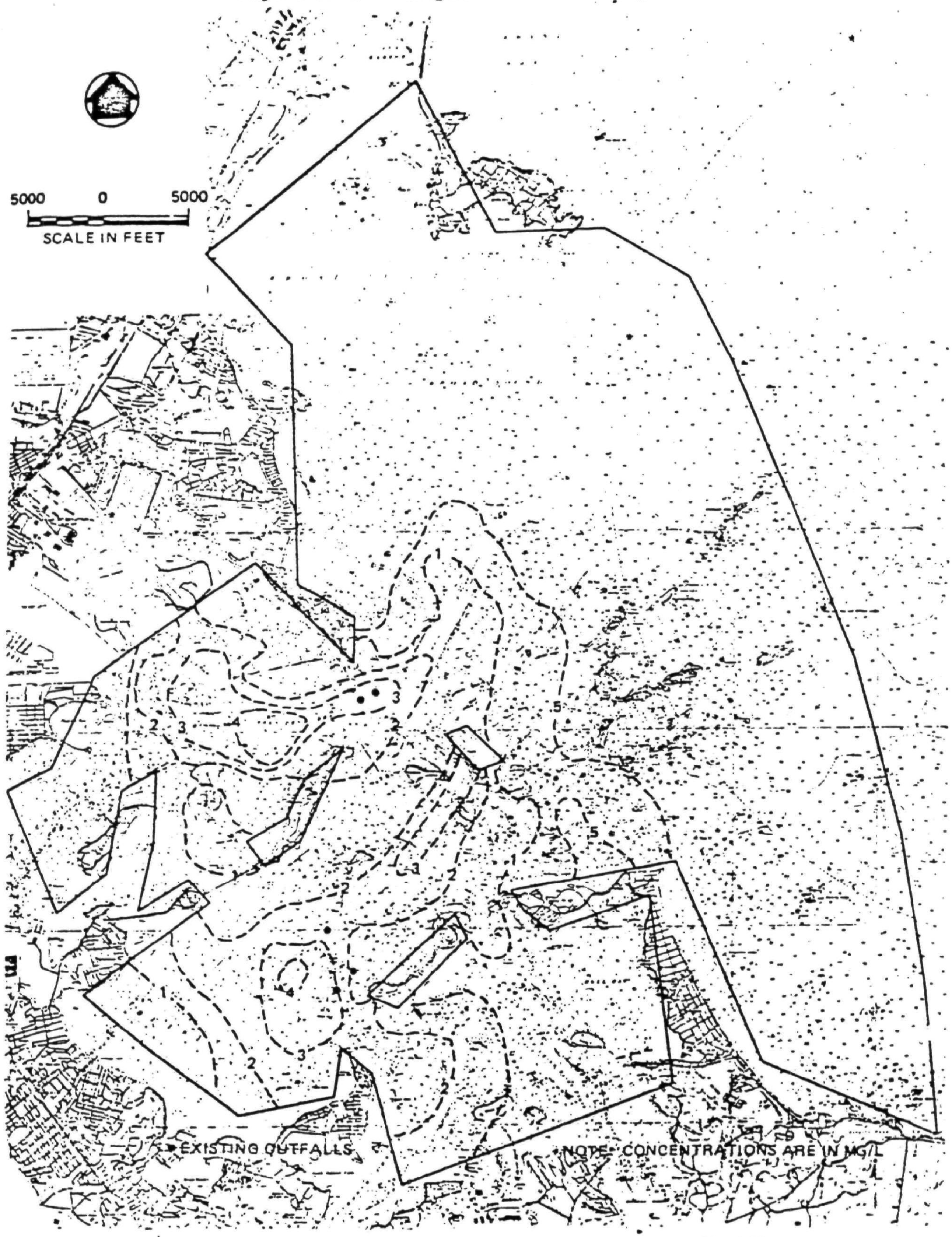
DISPER's greatest strength lies in its ability to predict volumetric inflows and outflows from the harbor area (across a specified, but imaginary, boundary). The model's next strongest capacity is its ability to predict water movement patterns (directions and magnitudes of flow). CAFE is largely responsible for these phases of the modeling effort. How STP effluent disperses through the harbor is the task addressed by DISPER. Whether pollutant loadings move exactly as does the water is unknown because settlement and decomposition in transport, propensities of marine organisms to assimilate wastes, etc., are not precisely understood.

The impact of, for example, the ocean outfall diffuser is assessed using a conservative solute and BOD, a substance which decays at a first order rate. For the conservative substance, decay and settling rates and concentrations along the ocean boundary are assumed to be zero. The source loading is input continuously and steady-state concentrations are computed. No other sources or sinks are modeled. The results of this modeling effort included contour lines of constant dilution and concentrations of ultimate BOD as incremental additions from the treatment option being modeled.

Model results available to Meta Systems for review were run by Metcalf and Eddy. (A sample of Metcalf and Eddy's DISPER output is shown in Figure A-1). Metcalf and Eddy suggest that their assumptions tend to be conservative (i.e., decay rate = zero, settling rate = zero).

The predicted water quality impacts due to the various STP treatment options presented in Section 4 of the main report were made through comparisons of the following types of information, often in the form of mappings:

Figure A-1. Example of DISPER Output



CONCENTRATIONS OF ULTIMATE BOD FROM TREATMENT PLANT EFFLUENT EXISTING CONDITIONS

Source: Metcalf & Eddy (1982), Figure 3-17.

- effluent pollutant concentrations;
- dispersion model output (DISPER); and
- water quality at various receptors (beaches, recreational areas, shellfish beds).

The receptor site, Brewsters Islands, is provided as an example of the way the calculations of percentage pollution reduction in Tables 4-2 and 4-3 of the main report were done.

(1) Current Ambient Water Quality at Brewsters Islands

Fecal coliform (MPN/100 ml)	10
BOD_5 (mg/l)	1
TSS (mg/l)	10-20

Source: Maps from Region I, EPA, Boston Harbor Data Management System, December 1983.

(2) Existing Concentration of Effluent

	Deer Island	Nut Island
Fecal coliform	1500	1500
BOD_5	127.6	105
TSS	121	110

Source: See Table 4-1, Section 4 of main report

(3) Existing Outfall Dilution Ratio 500 500 (at Brewsters Island)

Source: See Table 4-1, Section 4 of main report

(4) Existing STP Incremental Contribution (Deer and Nut combined) at Brewster Islands

Fecal coliform	6
BOD_5	.47
TSS	.46

Source: Effluent concentrations (2) divided by dilution ratios (3) summed for both Deer and Nut Islands.

(5) Portion of Ambient Water Quality not Due to Existing STP

Fecal coliform	4
BOD_5	.53
TSS	9.5-19.5

Source: Current ambient water quality (1) minus STP contribution (4).

(6) Effluent concentrations

	Ocean Outfall	Secondary Treatment
Fecal coliform	1500	1500
BOD_5	115	30
TSS	86	30

Source: See Table 4-1, Section 4 of main report.

(7) Dilution Ratio at Brewsters Islands

	200	500

Source: See Table 4-1, Section 4 of main report. Obtained from DISPER contour maps.

(8) Incremental Contribution from Treatment Option (at Brewsters Islands)

Fecal coliform	7.5	3
BOD_5	.57	.06
TSS	.43	.06

Source: Effluent concentration (6) divided by dilution ratio (7).

(9) Ambient Water Quality with Treatment Option (at Brewsters Islands)

Fecal coliform	11.5	7
BOD_5	1.11	.6
TSS	10-20	9.6-19.6

Source: Portion of ambient quality not due to existing STP (5) plus incremental contribution (8).

(10) Percentage Change in Water Quality (+ improvement / - degradation)

Fecal coliform	-15	+30
BOD_5	-11	+40
TSS	0	+2 to +4

Source: Current ambient quality (1) minus ambient quality with treatment option (9) divided by (1).

References

Dumanowski, Diane, 1982. The Boston Globe, December 19, 20, and 21, Boston, MA.

EcolSciences, March 1979. Environmental Impact Statement: MDC Proposed Sludge Management Plan, Metropolitan District Commission, Boston, MA, for Environmental Protection Agency, Region I, Boston, MA.

Environmental Research and Technology, 1978. Draft Report for the National Science Foundation, C-PRA77-15337.

Metcalf & Eddy, Inc., September 13, 1979. Application for Modification of Secondary Treatment Requirements for its Deer Island and Nut Island Effluent Discharges into Marine Waters, for Metropolitan District Commission, Boston, MA.

Metcalf & Eddy, Inc., June 1982. Nut Island Wastewater Treatment Plant Facilities Planning Project, Phase I, Site Options Study, for Metropolitan District Commission, Boston, MA.

Moore and Associates, Inc., H.E., September 1980. Wollaston Beach Exploration/Remedial Program Regarding Storm Water Contamination, Boston, MA.

Appendix B

Recreation Benefit Computations

B.1 Seasonal Swimming--Increased Participation

Increased participation in swimming due to pollution abatement control was calculated from current swimming participation and estimated unmet demand. The example below is for one pollution control option (CSO controls) for the swimming beaches in the study area.

Beach	Increase in Participation from Pollution Control	=	(A) % Pollution Abatement (CSO)	x	(B) Increased Demand (User days)
Constitution	113,750		70		162,500
Dorchester	236,000		80		295,000
Wollaston	1,100,000		80		1,375,000
Quincy	63,560		80		79,450
Weymouth	0		0		52,910
Hingham	0		0		11,100
Hull	0		0		33,000

(A) Source: Section 4 of main report.

(B) Beach	Increase Demand (User days)	=	(1) Proportion of entire SMSA swimming usage supplied by beach	x	(2) Unmet Demand in User Days
Constitution	146,250-178,750 avg = 162,500		.034		4,258,801-5,199,090
Dorchester	265,500-324,500 avg = 295,000		.062		4,258,801-5,199,090
Wollaston	1,237,500-1,512,500 avg = 1,375,000		.291		4,253,801-5,199,090
Quincy	71,505-87,395 avg = 79,450		.017		4,253,801-5,199,090
Weymouth	47,619-58,201 avg = 52,910		.011		4,253,801-5,199,090
Hingham	9,990-12,210 avg = 11,100		.002		4,253,801-5,199,090
Hull	29,700-36,300 avg = 33,000		.007		4,253,801-5,199,090

(1) Calculation of Proportion of Entire SMSA Swimming Usage Supplied by Beach

Constitution Beach is used as an example. Figures for all other beaches calculated in identical fashion.

	Proportion of SMSA Swimming Use Supplied by Beach		(a) Beach Attendance		(b) Total Seasonal SMSA Attendance
		=		÷	
Constitution	.034	=	325,000		9,452,892

(a) Source: Metropolitan District Commission and municipalities.
(b) Source: See 2b below.

(2) Unmet Demand in User Days

Unmet user days		(a) Percent unmet demand for swimming in SMSA		(b) participation in swimming days per year
	=		x	
4,253,801-5,199,090		45-55		9,454,892

(a) Source: Department of Environmental Management, Massachusetts Outdoors (SCORP) 1976 and discussions with cities and towns.

(b) Swimming Participants		(i) population SMSA		(ii) proportion participating in swimming		(iii) average # day trips
	=		x		x	
9,452,892		2,763,357		.32		10.69

(i) Source: 1980 Census

(ii) Source: Department of Interior, April 1984 (figure is for all U.S.).

(iii) Source: Abt Associates, New York-New England Study, 1979.

B.2 Seasonal Beach Capacity and Current Attendance

The calculations above, show estimated increased number of user days due to pollution control. It is necessary to compare the predicted increased use with the overall beach capacity so that the estimates doe not exceed the known capacity. The example beach capacity calculation is given for Constitution Beach. Table 6-1, Section 6 of the main report, presents the capacity figures for the beaches in the study area.

	seasonal beach capacity	=	(A) square feet of beach	÷	(B) square feet of beach per person	x	(C) persons per day turnover rate	x	(D) peak days per season
Constitution Beach:	468,864		264,000		50		3		29.6

(A) Source: Metropolitan District Commission, Boston, MA.

(B), (C) Source: Department of Interior, Outdoor Recreation Standards, 1970.

(D) Source: Department of Environmental Management, Massachusetts Outdoors (SCORP), 1976.

Capacities for all other beaches were calculated in a similar manner except for Wollaston Beach. The different assumptions used for Wollaston Beach were 40 square feet of beach per person and four persons per day turnover rate.

The predicted increased use is added to the current attendance figures before comparison with seasonal capacity. Table B-1 shows the current seasonal figures for the study area.

Table B-1.

Current Seasonal Attendance Figures

Beaches	MDC and Municipal Estimates 1982	MDC and Municipal Estimates 1974	Binkley/ Hanemann Estimate- Logit Model	Range	Best Guess
Constitution	150,000	500,000	1,258,571	150,000 - 1,258,571	325,000
Dorchester Bay					
Castle Island	15,000			15,000	15,000
Pleasure Bay	175,000			175,000	175,000
Carson	100,000			100,000	100,000
Malibu	150,000			150,000	150,000
Tenean	150,000			150,000	150,000
Wollaston	2,000,000 - 3,500,000	750,000	2,325,714	2,000,000 - 3,500,000	2,750,000
Quincy	140,194 - 177,600			140,194 - 177,600	158,927
Weymouth	103,600 - 108,040			103,600 - 108,040	105,820
Hingham	17,650 - 26,640			17,760 - 26,640	22,200
Hull	66,000			66,000	66,000

B.3 Lower Bound Estimate for Increased Participation

Not all the projected increased participation might occur because of relatively cold air temperatures at the beach, which might discourage increased beach visits even with improved water quality. The predicted increase in beach visits is reduced by a factor to take into account air temperature. It is derived as follows in order to obtain a lower bound estimates of increased participation.

(a) Each day of the summer season is categorized as
- o poor (air temperature $\leqslant 75^\circ$ Farenheit)
- o good (air temperature $> 75^\circ$ and $< 79^\circ$)
- o excellent (air temperature $\geqslant 79^\circ$)

Air temperature data is available for sampled days during the months of June, July and August, 1982 and 1983.

Source: Approach suggested and data supplied by Dr. Richard Burns, Region 1, Environmental Protection Agency, Boston, MA Categories based on "Weather Conditions that Lure People to the Beach" by P. Rosenson and J. Havens in Maritimes, University of Rhode Island, Graduate School of Oceanography, August 1977. Air temperature for Boston Harbor area from NOAA, National Ocean Survey data file.

(b) The percentage of days in each category is calculated based on a total of 85 days sampled during the summers of 1982 and 1983.

(c) For each category of day a proportion of the predicted increased participation due to improved water quality is assumed to take place. For excellent days all the predicted increase is included. However, the assumption is made that on good and poor days only two-thirds and one-third (respectively) of the predicted increase is retained because the cooler air temperatures would tend to limit the increase predicted from improved water quality.

Source: Based on graph of attendance versus daytime temperature for a Rhode Island beach in "Weather Conditions that Lure People to the Beach" by P. Rosenson and J. Havens in Maritimes, University of Rhode Island, Graduate School of Oceanography, August 1977.

(d) Multiplying the proportion of days in each category (b) by the proportion of the predicted increased participation (c) gives the factor by which the upper bound estimate is reduced in order to obtain a lower bound estimate which takes into account air temperature.

The following table presents these calculations:

		Poor $\leq 75^{\circ}$	Good $> 75^{\circ}$ and $< 79^{\circ}$	Excellent $\geq 79^{\circ}$	Total
(a)	No. of sampled days June, July, August, 1982 and 1983	36	12	37	85
(b)	Proportion of days in 1982 and 1983	.424	.141	.435	1.00
(c)	Proportion of projected increase in participation not limited by air temperature	.33	.67	1.00	--
(d)	"Reduction factor" for lower bound : (b) x (c)	.140	.094	.435	.669

The total predicted increased participation is mulitiplied by the sum of the reduction factors to obtain the lower bound estimate of increased participation. For example, the upper bound predicted increase in participation for Constitution Beach is 113,750. The lower bound estimate is, therefore, .669 x 113,750 = 76,099.

B.4 The Conditional Multinomial Logit Model, in Brief

This section describes the conditional multinomial logit model of multiple site demand. The model works from the indirect utility function for an individual. The utility u_{ij} individual i receives from visiting beach j is

$$u_{ij} = f(d_{ij}, S_j, I_i) \qquad (B.1)$$

where

d_{ij} = travel cost (perhaps time and distance) for individual i to reach beach j

S_j = characteristics of beach j (perhaps a vector of characteristics).

I_i = characteristics of individual i (perhaps a vector of characteristics).

Individual i will choose beach j if and only if

$$u_{ij} > u_{ik} \quad k \neq j \qquad (B.2)$$

Suppose we recognize that the choice process is not perfect, either because the individual has imperfect information, makes "mistakes" in beach choice, or perhaps we do not recognize all the relevant factors in her utility function. Then we might model the indirect utility functions as

$$u_{ij} = v_{ij} + e_j \qquad (B.3)$$

where e_j is an error term capturing the error in the choice process and v_{ij} represents the measurable, nonstochastic part of the indirect utility function.

Now the probability of individual i choosing beach j is

$$P_{ij} = \text{prob} \left\{ u_{ij} > u_{ik} \right\} = \text{prob} \left\{ v_{ij} + e_j > v_{ik} + e_k \right\}$$
$$= \text{prob} \left\{ v_{ij} - v_{ik} > e_j - e_k \right\} \quad k \neq j \qquad \text{(B.4)}$$

McFadden (1973) proved that if e_j and e_k are independent with a Weibull distribution, then

$$P_{ij} = \exp(v_{ij}) / \sum_K \exp(v_{ik}) \qquad \text{(B.5)}$$

If the nonstochastic part of the utility function, v, is specified to be linear in parameters then (B.5) can be estimated using maximum likelihood methods and hypotheses can be tested in that framework as well.

Our model predicts the total number of visits by individual i to site j, n_{ij}, as

$$n_{ij} = n_i P_{ij} \qquad \text{(B.6)}$$

where n_i = the total number of visits by individual i.

In essence (B.6) factors a joint probability model into a conditional probability model. The underlying joint probability model predicts the probability of making a beach visit (instead of, say, going to a movie) and the probability of visiting a specific beach. Ben-Akiva (1973) showed the joint model can be factored with the inclusion of a particular term in the total visit model. The so-called "inclusive price" (IP) term reflects the service characteristics of the set of beaches:

$$IP_i = \sum_K \exp(v_{ik}) \qquad \text{(B.7)}$$

Then the total visit model can be specified as

$$n_i = g(IP_i, I_i). \qquad \text{(B.8)}$$

Together (B.6), (B.5) and (B.8) permit one to model how changes in site characteristics S_j will effect the total quantity of visits and the split of visits among the various beaches. That is, we estimate the parameters of these equations by using the data described above. To simulate the effect of a change in the characteristic of one or more of the sites, use (B.8) to find the total number of visits, (B.5) to find the fraction of the visits which will be made to each site and (B.6) to determine the number of visits made to each site.

The benefits of the simulated change in water quality at one or more sites can be estimated using a modification of a procedure developed by Small and Rosen (1982) and adapted to this problem by Feenberg and Mills (1980). The outline of this procedure is as follows. Include the minimum level of expenditure necessary to achieve a given utility level in v. Differentiate v with respect to expenditures to obtain an expression for the change in expenditures as a function of a change in site characteristics. This is a compensated demand function for the site characteristic. Then integrate this expression over a change in site characteristics to obtain an estimate of the welfare change associated with the change in site characteristics. The following makes this argument more specific.

$$V_{ij} = v(d_{ij}, S_j, I_i, E_i) \qquad \text{(B.9)}$$

where E is the minimum expenditure for individual i to obtain utility level v given all the other parameters.

Then

$$\frac{E_i}{S_j} = - \frac{1}{\partial V / \partial E_i} \frac{\partial V}{\partial S_j} = - \frac{1}{\lambda} \frac{\partial V}{\partial E_j} \qquad \text{(B.10)}$$

where λ_i is the marginal utility of income.

From Roy's identity $\lambda_i = \frac{\partial V}{\partial d} \Big/ n_i$. Then, in expectation,

$$\frac{\partial E_i}{\partial S_j} = -\sum_j P_{ij} \; n_i \; \frac{\partial V}{\partial S_j} \Big/ \frac{\partial V}{\partial d_{ij}} \qquad \text{(B.11)}$$

We know P_{ij} from (B.5). Further, specify (B.8) in power function form so that

$$n_i = \alpha_i \left[\sum_K \exp\,(V_{ik}) \right]^{\alpha_2}$$

Substituting into (B.11) gives

$$\frac{E_i}{S_j} = - \sum_j \alpha_i \left(\sum_K \exp V_k \right)^{\alpha_2 - 1} \exp V_{ij} \Big/ \frac{\partial V}{\partial d} \qquad \text{(B.12)}$$

To find the welfare change associated with a change in site characteristics S_j^o to S_j^1 where the characteristics might change in more than one site we integrate this expression between those limits. That is:

$$EV_i = \oint_{-S_j^o}^{S_j^1} \sum_j \frac{\partial E_i}{\partial S_j} ds_j$$

$$= \frac{\alpha_i}{\frac{\partial V}{\partial d}} \sum_j \left[\left(\sum_k \exp V_{ik} \right)^{\alpha_2} \right]_{S_j^o}^{S_j^1}$$

$$= (n_i(S_j^1) - n_i(S_j^0)) / \frac{\partial V}{\partial d} \cdot \alpha_2 \qquad \text{(B.13)}$$

Table B-2.

Sites Included in Logit Model [a]

Site Number	Site Name/Location	Site Ownership
1.	Kings Beach (Swampscott)	MDC
2.	Lynn Beach (Lynn)	MDC
3.	Nahant Beach (Nahant)	MDC
4.	Revere Beach (Revere)	MDC
5.	Short Beach (Revere)	MDC
6.	Winthrop Beach (Winthrop)	MDC
7.	Constitution Beach/Orient Heights (Boston)	MDC
8.	Castle Island (Boston)	MDC
9.	Pleasure Bay (Boston)	MDC
10.	City Point (Boston)	MDC
11.	L & M Street Beaches (Boston)	Boston
12.	Carson Beach (Boston)	MDC
13.	Malibu Beach/Savin Hill (Boston)	MDC
14.	Tenean Beach (Boston)	MDC
15.	Wollaston Beach (Quincy)	MDC
16.	Nantasket Beach (Hull)	MDC
17.	Wingaersheek Beach (Gloucester)	Gloucester
18.	Crane's Beach (Ipswich)	Private
19.	Plum Island (Newbury)	Private
20.	Duxbury Beach (Duxbury)	Private
21.	White Horse Beach (Plymouth)	MDC
22.	Breakheart Reservation (Saugus)	MDC
23.	Sandy Beach/Upper Mystic Lake (Winchester)	MDC
24.	Houghton's Pond/Blue Hills Reservation (Milton)	MDC
25.	Wright's Pond (Medford)	DNR
26.	Walden Pond (Concord)	DNR
27.	Stearns Pond/Harold Parker State Forest (Andover)	DNR
28.	Cochituate State Park (Natick)	DNR
29.	Hopkinton State Park (Hopkinton)	DNR

[a] Based on Data collected by Binkley and Hanemann, 1975.

B.5 Beach Closings

Beach closings were calculated using seasonal attendance and water quality data. They were calculated for water quality levels greater than 200 and 500 MPN/100 ml fecal coliform and, in certain cases, for 700 MPN/100 ml total coliform.

Tenean Beach, at water quality level >500 MPN/100 ml and for the CSO control option is used as an example. Beach closings for all other affected beaches were similarly calculated.

Beach	Number of Beach Closings Averted (Visitor Days)	=	(1) Number of Beach Closings Under Present Conditions (Visitor Days)	x	(2) % Pollution Abatement From Control Options
Tenean	19,286	=	24,107		80

(1) Current Beach Closings

Number Beach Closings (Visitor Days)	=	(a) % of Season Water Quality >500 MPN	x	(b) Seasonal Attendance
24,107	=	.1607		150,000

(a) Source: Meta Systems calculations based on data from Metropolitan District Commission and towns of Quincy, Weymouth, Hingham, and Hull.

(b) Source: See Table B-1 (above).

(2) Source: See Table 4-3, Section 4 of the main report.

B.6 User Day Values

Many of the recreation benefit estimation approaches calculate the value of benefits accruing from changes in the use of a resource by applying a specific dollar value to an incremental change in quantity of recreation. These user day values (also called unit day values) have been calculated using a variety of techniques including cost of travel and survey-derived estimates of willingness to pay. Generally an average figure is given which may not reflect the effects of incremental changes in environmental quality. They should be applied with care especially when user day values derived in one area of the country are applied to a different region. Table B-3 presents the (wide) range of values to be found in the literature and which are potentially applicable to this case study.

Table B-3. User Day Values

Source	User Day Value in Study	User Day Value[a] in 1982 $	Values Chosen for use in Boston Harbor Study
General Recreation or Swimming			
Heintz *et al.*	2.67 (1973 $)	5.80	Harbor (moderate)
DPRA	2.54 (1975 $)	4.56	
Binkley Logit Model[b]	5.65 (1974 $)	11.06	Harbor (high)
Federal Register	1.60 to 4.80 (1982 $)	1.60 to 4.80	Harbor (low)
Boating			
Heintz *et al.*	8.96 (1973 $)	19.46	
DPRA	5.17 (1975 $)	9.27	Charles River (low)
Charbonneau and Hay[c]	22.80 (1975 $)	40.89	Harbor (high)
NPA	12.26 (1978 $)	18.14	Charles River (high), Harbor (low)
Fishing			
Heintz *et al.*	8.74 (1973 $)	18.98	
DPRA	5.15 (1975 $)	9.24	
Charbonneau and Hay			
Trout	21.00 (1975 $)	37.66	
Bass	19.00 (1975 $)	34.08	Harbor (high)
Catfish	15.00 (1975 $)	26.90	
Russell and Vaughan[d]			
Trout	11.10-24.10 (1979 $)	14.76-32.05	
Bass	9.70-21.40 (1979 $)	12.90-28.46	
Catfish	7.00-16.00 (1979 $)	9.31-21.28	
Survey of Fishing	11.00 (1980 $)	12.89	Harbor (low)
Federal Register			
General	2.30-4.80 (1982 $)	2.30-4.80	
Specialized	11.20-19.00 (1982 $)	11.20-19.00	

a/ Updated using Consumer Price Index, U.S. City Average, All Urban Consumers, average for 1982 (CPI-U=289.1).
b/ As presented in Appendix B.3 and Section 6 of main report.
c/ Assuming a ratio of boating to fishing (bass) of 1:2.
d/ Lower figure assumes fees reflect real resource costs and value of travel time is zero (net consumer surplus). Higher figure assumes fees are pure transfers and value of travel time is average wage rate (total willingness to pay).

References for Table B-3.

Charbonneau, J. and J. Hay, 1978, "Determinants and Economic Values of Hunting and Fishing," Paper presented at the 43rd North American Wildlife and Natural Resource Conference, Phoenix, Arizona.

Development Planning and Research Associates, Inc. (DPRA), 1976, National Benefits of Achieving the 1977, 1983 and 1985 Water Quality Goals, Environmental Protection Agency, Office of Research and Development, Washington, DC.

Federal Register, Volume 48, Number 48, March 10, 1983, "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies", U.S. Water Resources Council, Washington, DC.

Heintz, H.T., A. Hershaft and G.C. Horak, 1976, National Damages of Air and Water Pollution, Environmental Protection Agency, Office of Research and Development, Washington, DC.

National Planning Association (NPA), 1975, Water-Related Recreation Benefits Resulting from Public Law 92-500, National Commission on Water Quality, Washington, DC.

Russell, C.S. and W.T. Vaughan, 1982, "The National Fishing Benefits of Water Pollution Control," Journal of Environmental Economics and Management, 9:328-353.

U.S. Department of the Interior, 1982, 1980 Survey of Fishing, Hunting and Wildlife Associated Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

B.7 Sources of Recreation Data

Information pertaining to recreation participation and the corresponding economic values were drawn from a number of existing reports. Not all of the information is specific to Boston Harbor, nor does each address exactly what is needed for the case study at hand. However, it is information that can be used to define ranges of values for both participation rates in and economic values derived from the water resources of Boston Harbor. In order to ascertain how the figures proposed by each source relates to this case study, the method of their derivation and the populations from which they were derived must be examined and compared to the objectives of this study and to the population using (or potentially using) Boston Harbor's water resources.

1. Abt Associates, 1979. New York-New England Recreational Demand Study, Vol. I and II. Cambridge, MA.

The focal point of this study was a survey designed to (1) quantify current recreational demands in the New York-New England region and, then, (2) to use that demand to develop a model of supply/demand interactions of recreational resource availability and needs of forecasting recreational demands.

The current demand figures from this study can be applied to the Boston Harbor case study because the statistical techniques used were thorough (including the breakdown of information by useful characteristics) and because the sample size was large. The forecasted recreational data is not applicable to Boston Harbor. One of the criticisms of the study is that demand forecasts are a dependent variable of supply. To accurately assess the particular effects of increasing the water quality of Boston Harbor, it would be preferable to use Boston Harbor-specific supply information in the model. The results forecasted by this study's model are based upon much larger geographic areas of recreational resources and thus do not directly help in pin-pointing the benefits accrued (real or potential) from improved harbor water quality.

2. U.S. Department of the Interior, November 1982. 1980 National Survey of Fishing, Hunting, and Wildlife Associated Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

Every five years, since 1955, the Fish and Wildlife Service (in cooperation with the Bureau of Census) has conducted a nationwide survey of U.S. fishing and hunting activities. For the 1980 survey, questions about non-consumptive wildlife associated recreation (e.g., bird watching) were asked for the first time. Much of the information is of use to the Boston Harbor case study, including participation rates, level of participation intensity, and expenditures per activity. Unfortunately, there are no willingness to pay or latent demand analyses.

The survey's strongest recommendation is its large sample size, which lends confidence to statistical analyses derived from its data base. Over 116,000 households were sampled nationwide to determine participation rates in various wildlife-related activities. Of particular interest and application to the Boston Harbor case study are the statistics obtained for saltwater fishing. Fishing participants identified in the screening phase of the survey were re-interviewed, with attention to more details about:

- o their intensities of participation (number of trips and days per year);
- o location of activity (fresh or saltwater, in-state or out-of-state);
- o mode of participation (boat, surf, shore, pier, etc.);

- expenditures for participating in the activity; and
- demographic characteristics of the participants.

For this second phase of data collection, "sample sizes were designed to provide statistically reliable results at the state level for fishing and hunting and at the Census geographic division level for non-consumptive activities".[a] In Massachusetts, 700 fishermen and women were interviewed. Of those interviewed, 272 participated in saltwater fishing only (39 percent of Massachusetts anglers), and 219 engaged in both fresh and saltwater fishing (31 percent).

Since the statistics above are for Massachusetts overall, it is necessary to consider how Boston area anglers differ from the "average" Massachusetts anglers. Given fishing as an activity of participation, participation rate differences between Massachusetts residents state-wide and Boston SMSA residents are considered. The proximity of saltwater resources to Boston suggests that the salt and freshwater fishing participation ratio might be even higher for the Boston area. Assuming that the greatest use of Boston Harbor is made by the local population, this is an important consideration and it suggests that the survey's results are a lower bound estimate of saltwater fishing participation. What might cause the survey's estimates to be overstatements for the Boston SMSA are the characteristics of Cape Cod and the shoreline communities to the north and south of Boston. These three areas are apt to have higher than average fishing participation rates assuming that individuals who like to engage is this activity are prone to reside in these areas. A statistically equivalent sampling of these areas could skew state-wide participation rates upward.

---

[a] Page viii of the survey.

The survey also presents participation rates by geographic area and place of residence. For New England, the saltwater fishing geographic/demographic distinctions are made for big cities, small cities and rural areas. Boston, however, is rather uniquely situated with respect to most other cities of New England because it is on the Atlantic Coast. Again, if proximity of the resource does have bearing on participation, then the study estimates are probably underestimates of Boston SMSA fishing rates. The days of participation figures generated by the survey are consistent with the same measure from other studies. A final recommendation of this survey is that it was completed quite recently (1980-1982).

3. McConnell, K.E., Smith, T.P., and Farrell, J.F., 1981. Marine Sportfishing in Rhode Island 1978. NOAA/Sea Grant, University of Rhode Island Technical Report 83, Narragansett, Rhode Island.

This study is recommended for a number of reasons, including:

- The data was collected recently, from February 1978 to January 1979;
- The sample size is large, implying statistical confidence (5,000 interviews were conducted at the sites of the fishing experiences and 9,000 phone interviews were conducted state-wide);
- The information collected pertains specifically to saltwater fishing;
- The geographic proximity of Rhode Island to Boston Harbor makes for similar fishing experiences in terms of the types of fish caught and the general environmental experience (weather, topography, vegetation, seasons); and
- The nearness of Rhode Island to the case study area captures similar population characteristics such as attitudes, lifestyles, economic activities, etc.

There are a few obvious differences between the two study areas. One difference is that the vast majority of fishing in Rhode Island does not take place near urbanized areas. Another is that public transportation is used less often in Rhode Island than in the Boston SMSA, suggesting that travel mode arguments are not identical for the areas. Travel time is comparable however, because of Rhode Island's small size. For instance, the travel time from Rhode Island's population centers in the northern part of the state (including Providence, the capitol) to the southern shores (popular fishing spots) is usually an hour or less by car; using Boston public transportation to visit a fishing site in and around the Harbor requires a comparable amount of time.

In addition to participation rate and intensity information, estimates of economic expenditures for participation are also available from this study. Average expenditures are based on "out-of-pocket" costs per trip which may or may not include some travel costs (for instance, if gas was bought on the trip, then it would partially account for travel costs). An examination of costs per trip and one-way mileage figures suggests that travel costs are not extensively covered by the "out-of-pocket" cost data; even at the conservative cost of $.10 per mile, the expenditure data barely accounts for travel costs.

By using the expenditure information available for the various modes of fishing (shore, fixed structure, boat) together with travel cost information specific to Boston Harbor, a range of plausible current trip expenditures for fishing in the Harbor can be calculated. Such a range represents demonstrated economic worth of the fishing resources but does not indicate consumer (participant) surplus of fishing activity.

The interview questionnaire used for this study did include willingness to pay questions, but that data has not yet been tabulated and analyzed. In the absence of willingness-to-pay measures, the demonstrated expenditures will be taken as lower bound estimates of the economic value of Boston Harbor's fishing resources.

4. Metcalf and Eddy, 1975. Eastern Massachusetts Metropolitan Area Study (EMMA). Technical Data (Volume 13B). Socio-Economic Impact Analysis.

The area of study for the EMMA series of reports roughly corresponds to the area of this case study, so the information presented is directly relevant to the case study at hand. The socio-economic impact analysis includes a section on recreation in the area. It examines actual and potential recreational activity there. Actual, or current, activity is defined as demand; potential activity, or un-met demand, is defined as need. (Need is translated as latent demand for application to this case study.)

Much of the information presented in EMMA regarding recreational opportunities is drawn from the Eastern Massachusetts supplement to the 1972 Massachusetts Outdoor Recreation Plan. Based on information drawn from the Outdoor Recreation and Open-Space Inventory and from census data, the supplement provides a data baseline on recreational opportunity in the area. Although the inventory and census were conducted in 1970, the recreational opportunity and activity calculations are still valid since the current population and recreational resources of the area are not much changed from that time, if recreational habits are also alike.

The assessments of demand and latent demand were performed according to population density groups within the MAPC area. The highest density groups had the lowest ratios of recreation and open space acreage to population. It appears that the analyses for latent demand were performed within each density group; that is, if the recreational resources within a density group area were not sufficient to meet the total potential demand for the population within that group, the availability of such resources in other areas was not considered for satisfaction of those recreation needs. The high density areas exhibit latent demand of water-based recreational activities, even though the majority of municipal recreational sites is within the very dense and dense categories. Still, the extremely dense category has five percent of the recreational areas and 35 percent of the population within the study area.

The quality of the available recreational sites was not a factor in calculating recreational opportunity.

5. Metropolitan Area Planning Council, October, 1972. Boston Harbor Islands Comprehensive Plan, for Massachusetts Department of Natural Resources.

This report describes a plan for all phases and aspects of maintaining and developing the islands of Boston Harbor, which are considered a unique natural resource of significance to the New England Region. The islands are predominantly open, natural areas; some have historic sites or limited public facilities. The Plan contains descriptions of the islands and the current and planned activities for them. Many of the islands do not yet have the facilities or the water quality necessary for some of the activities; therefore, activity days figures most nearly reflect potential use of the Islands.

The islands offer a range of activities: swimming, boating, fishing, hiking, picnicking, group and primitive camping, play, and historic fort visitation. Only the first three activities mentioned are of concern to this case study because they are most directly affected by water quality. (However, water quality can affect the experiences of other activities such as camping and hiking.) This report is particularly useful because it provides data on the recreational potential (activity days) of the Harbor Islands.

The economic values per day for each Boston Harbor Island activity day were based upon the Federal Water Resources Council's "Standards for Planning Water and Land Resources" (July 1970). These values are nationwide estimates. Because the values in the Harbor Plan are in 1970 dollars it was necessary to inflate them to 1980 dollars using the Consumer Price Index for urban consumers. Furthermore, the round trip ferry fee to George's Island of \$3.00 has been added to the value in order to account for a portion of the travel costs incurred in visiting the islands. The Department of Environmental Management provides a free taxi service to reach other islands from George's Island. The travel costs incurred by private boaters to the islands are probably at least \$3.00 considering the costs of gas and/or costs of upkeep.

6. Bureau of Outdoor Recreation, September, 1977. National Urban Recreation Study: Boston/Lowell/Lawrence/Haverhill, Northeast Regional Office; National Park Service and Forest Service.

This particular study offers qualitative insights into and justifications for recreational resource preservation in its study area. (Some of the ideas are presented here.) A basic premise of the study is that open space which is close to home is desirable. At present, Boston has only 5.4 acres of open space per thousand population, whereas the recommended minimum by the National Recreation and Park Association and the Urban Land Institute is 10 acres per thousand population. Most of Boston's land is already developed. Once it has been developed, it is economically and physically difficult to reclaim as open space. Of the open spaces that do remain, there is considerable competition for their use.

Only about one-sixth of New England's coastline is accessible to the general public. The recreational potential that Boston Harbor offers is substantial by comparison since approximately 40 percent of the harbor shoreline remains relatively undeveloped; portions of this undeveloped area are used for recreational activities. In addition, the islands are within a 25 mile radius of 2.7 million people. The 1977 Coastal Zone Management Plan lists three types of recreational facilities as being in greatest demand for Boston Harbor. They are: (1) large scale beaches and waterfront parks; (2) smaller scale beaches and parks for local use; (3) walkways. Certainly, water quality is critical to swimming activity and can enhance the enjoyment of parks and walkways.

Whereas the waterfront was once largely an area of warehousing and industrial activity, new development and redevelopment styles are leading to different interactions with the Harbor, particularly in the downtown areas along the Inner Harbor. More people are living, shopping, and staying in hotels near the water--their relationship to the Harbor is becoming more intimate so the aesthetic quality and sense of open space it can offer is becoming more important. Furthermore, as more white-collar businesses move into the waterfront commercial spaces, perceptions and expectations of the working environment change (visits by clientele, visual appearances of surroundings, etc.).

7. Massachusetts Department of Environmental Management, December 1976. Massachusetts Outdoors: Statewide Comprehensive Outdoor Recreation Plan (SCORP).

The information on recreation participation rates and latent demand in this report is of interest to the Boston Harbor case study. However, the methodology employed to obtain that information has a number of limitations. The primary problem is the sample size of the data collection effort.

A telephone survey was conducted of 400 households/persons throughout Massachusetts and this survey is the data source for all subsequent analyses. The Boston SMSA is contained within a region extending west to Worcester, north to the state border, and south to Bridgewater. This region is one of seven equally sampled areas within the state, meaning that the Boston SMSA recreational demand is calculated from only 57 (or fewer) interviews.

Some of the results of the data analysis are counter-intuitive. One such result suggests that power boating participation rates are more strongly associated with low income groups than with higher income groups, although power boat operation and maintenance can be quite expensive. Information from the "Boston Marinas and Live-Aboards Study" indicates a high proportion of large boats in the Boston area, thus countering the explanation that the power boat population is dominated by small boats with outboard motors (i.e., less expensive power boats, affordable to low income groups).

The results of the SCORP study are more meaningful if they are interpreted qualitatively, rather than quantitatively. The shortcomings of the empirical findings are often mentioned by the authors throughout the study, suggesting that SCORP results should be applied with caution.

8. Department of Interior, April 1984. The 1982-1983 Nationwide Recreation Survey, National Park Service, Washington, DC.

The most recent nationwide survey of recreation activities was designed for comparability with certain portions of the national recreation surveys conducted in 1960 and 1965. It includes data on participation rates, expenditures, reasons for recreating, and reasons for constraints on recreating. At the time of this report only nationwide figures were available. Regional (but not as detailed as the SMSA level) figures are expected to be published later.

References

Abt Associates, 1979. New York-New England Recreational Demand Study, Volumes I and II, Cambridge, MA.

Ben-Akiva, J., 1973. The Structure of Passenger Travel Demand, Ph.D. dissertation, Massachusetts Institute of Technology, Department of Civil Engineering, Cambridge, MA.

Binkley, Clark S. and W. Michael Hanemann, 1975. The Recreation Benefits of Water Quality Improvement, NTIS PB257719, for the U.S. Environmental Protection Agency, Washington, DC.

Department of Interior, March 1970. Outdoor Recreation Standards, Bureau of Outdoor Recreation, Washington, DC.

Department of Interior, September 1977. National Urban Recreation Study: Boston/Lowell/Lawrence/Haverhill, Northeast Regional Office, Bureau of Outdoor Recreation, National Park Service and Forest Service, Boston, MA.

Department of Interior, November 1982. 1980 National Survey of Fishing, Hunting and Wildlife Association Recreation, Fish and Wildlife Service and U.S. Department of Commerce, Bureau of the Census, Washington, DC.

Department of Interior, April 1984. The 1982-1983 Nationwide Recreation Survey: Summary of Selected Findings, National Park Service, Washington, DC

Feenberg, Daniel and Edwin Mills, 1980. Measuring the Benefits of Water Pollution Abatement, Academic Press, New York, NY.

Massachusetts Department of Environmental Management, December 1976. Massachusetts Outdoors: Statewide Commprehensive Outdoor Recreation Plan (SCORP), Boston, MA.

McConnell, K.E., Smith, T.P. and Farrell, J.F., 1981. Marine Sportfishing in Rhode Island 1978, NOAA/Sea Grant, University of Rhode Island Technical Report 83, Narragansett, RI.

Metcalf and Eddy, 1975. Eastern Massachusetts Metropolitan Area Study (EMMA), Boston, MA.

Metropolitan Area Planning Council, October 1982. Boston Harbor Islands Comprehensive Plan, for Massachusetts Department of Natural Resources, Boston, MA.

Small, K and H. Rosen, 1981. Applied Welfare Economics with Discrete Choice Models, Econometrica 40: 105-130.

Appendix C

Swimming Health Benefit Calculations

Health benefits for recreational swimming are derived using dose-response functions and beach attendance data. The distribution of water quality levels throughout the swimming season for each beach was used as the basis for estimating the exposure of the swimming population. The first section of this appendix shows how the number of highly credible gastroenteritis cases was calculated for each water quality level at each beach. Tenean beach, at water quality level 7 (60 MPN fecal coliforms per 100 ml), is used as a representative example. The second section of this appendix shows the calculations of reduced number of cases of illnesses for each treatment option for each beach.

C.1 Number of Cases of Gastrointestinal Illness
(Tenean Beach, water quality level 7)

Number of Cases of Highly Credible Gastroenteritis At Water Quality Level 7		(A) Number of Cases of HC gastroenteritis per 1000		(B) Population at Risk, up to Water Quality Level 7		
190	=	18.09		10,500		

(A) Number of cases per 1000	=	(1) 0.2 + 12.2 log *Enterococci*	R^2 = 0.75
18.09	=	0.2 + 12.2 x 1.47	

Source: Cabelli *et. al*, 1982.

$$\text{(1)}\quad \text{Log } \underline{\text{Enterococci}} = 0.825 \log \underline{\text{Fecal coliform}}^{(a)} \qquad R^2 = 0.82$$

$$1.47 = 0.825 \times \log(60)$$

Source: Meta derived statistical relationship using averaged MDC and other municipal water quality data, 1974-1982.

(a) When total coliform concentrations were measured instead of fecal coliform concentrations, total coliform concentrations were substituted using the following relationship:

$$\log \underline{\text{Fecal coliform}} = 0.65 \log \underline{\text{total coliform}} \qquad R^2 = 0.89$$

Source: Meta derived function, based on averaged MDC and municipal water quality data, 1974-1982.

(B) Population at Risk at Water Quality Level 7		(1) Seasonal Beach Attendance		(2) Percentage of Season Water Quality At Level 7
10,500	=	150,000	x	.07

(1) Source: MDC, Towns of Quincy, Weymouth, Hingham and Hull.

(2) The frequency, per season, of thirteen water quality levels was measured for fecal coliform concentrations, MPN per 100 ml (see Table C-1).

C.2 Reduced Cases of Gastrointestinal Illness

The above calculations are done for each water quality level to establish the base case for each beach. This gives the estimated number of cases of illness occurring under current conditions. Similarly, the calculations can be carried out assuming a certain percentage of pollution reduction. This is done by reducing the average fecal coliform count for the water quality level by the percentage pollutant reduction. For example, in the base case water quality level 7 has a fecal coliform count of 60 MPN/100 ml.

Table C-1. Water Quality Fecal Coliform Levels

Level	Water Quality Range Fecal Coliform	Median Value Fecal Coliform Used	% During Season for Tenean Beach
1	0	0	0
2	1-5	3	10
3	6-10	8	13
4	11-20	15	9
5	21-30	25	1
6	31-50	40	12
7	51-70	60	7
8	71-130	100	9
9	131-170	150	7
10	171-330	250	9
11	331-470	400	6
12	471-730	600	9
13	≥ 731	731	10

Under the CSO control option with 80 percent reduction the same water quality level 7 would be assigned a fecal coliform count of 12 MPN/100 ml. Then, the string of calculations listed in Section C.1 above are repeated to estimate the number of cases of illness under these new water quality conditions. The number of cases for each of the water quality levels are summed to give a total incidence of illness at that beach. Levels for which the fecal coliform counts exceed 500 MPN/100 ml, however, are not included because we assume the beach is closed to swimming at counts above 500 MPN/100 ml. These calculations are shown for Tenean Beach in Table C-2.

C.3 Population at Risk

The studies of swimmers and related health effects divide the population of visitors to a beach into swimmers and non-swimmers. Two available studies have this information for Boston area beaches. Their results are shown below.

Study	Total # of Visitors	% of Swimmers who go swimming
43 Boston area beaches (Hanemann, 1978)	2507	32 %
2 Boston area beaches (Cabelli *et al.*, 1980)	4153	49 %
6 Coastal beaches in U.S. (Cabelli *et al.*, 1980)	16182	63 %

In this study we use the figure of 4[illegible]6 for a lower bound estimate of the population at risk. In addition, a reduction factor tied to the distribution of air and water temperature during the summer season is used. This factor is calculated by first categorizing the summer days as follows:

Table C-2. Calculation of Number of Highly Credible Gastroenteritis Cases for Tenean Beach

Level	Fecal Coliform Count (average)[a]	% of Season Water Quality at Given Level[a]	# of Base Cases[b]	With 10% Reduction: f.c. Count[c]	With 10% Reduction: # of Cases[b]	With 80% Reduction: f.c. Count[c]	With 80% Reduction: # of Cases[b]	With 90% Reduction: f.c. Count[c]	With 90% Reduction: # of Cases[b]
1	0	0	0	0	0	0	0	0	0
2	3	10	73	2.7	66	0.6	0	0.3	0
3	8	13	181	7.2	172	1.6	41	0.8	0
4	15	9	163	13.5	157	3	66	1.5	24
5	25	1	22	22.5	21	5	11	2.5	6
6	40	12	296	36	288	8	167	4	111
7	60	7	192	54	187	12	116	6	84
8	100	9	277	90	271	20	180	10	137
9	150	7	235	135	230	30	159	15	127
10	250	9	332	225	326	50	235	25	194
11	400	6	240	360	236	80	176	40	148
12	600	9	385	540	379	120	288	60	246
13	731	10	441	657.9	434	146.2	333	73.1	287
Total Cases			2837		2767		1772		1364
Total Cases below 500 MPN/100 ml			2011 (a)		1954 (b)		1772 (c)		1364 (d)

Calculations for Each Treatment Option

Treatment Option	% Pollution Reduction	Number of Reduced Cases of Illness	Calculation Method
CSO only	80	239	(a) - (c)
Ocean Outfall	10	57	(a) - (b)
Secondary Treatment	10	57	(a) - (b)
CSO and Ocean Outfall	90	647	(a) - (d)
CSO and Secondary Treatment	90	647	(a) - (d)

[a]From Table C-1.

[b]Calculated using Cabelli et al. (1982) equation.

[c][illegible] percentage reduction applied to levels in Table C-1

- Poor (air temperature $\leq 75^{\circ}$ Fahrenheit and/or water temperature $< 65^{\circ}$ Fahrenheit)
- good (air temperature $> 75^{\circ}$ and $< 79^{\circ}$ <u>and</u> water temperature $\geq 65^{\circ}$)
- excellent (air temperature $\geq 79^{\circ}$ <u>and</u> water temperature $\geq 65^{\circ}$)

Then, the distribution of days in each category is estimated from data on air and surface water temperature for the months of June, July and August for the years 1982 and 1983.. For "poor" days it is assumed that only one-third of the predicted increased population at risk will actually go swimming. For "good" days it is assumed that two-thirds of the predicted increase due to improved water quality will go swimming but not all of the predicted increase because of the relatively lower air and water temperatures. For "excellent" days, all of the predicted increased population at risk is assumed to go swimming.

Thus, the lower bound estimate of increased population at risk is 49% of the predicted increased beach visitors times the reduction factor (.551) for the air and water temperature constraints. We used 100% of beach visitors as an upper bound estimate because the question in the studies is often phrased "what is your primary beach activity" rather than "did you go swimming". Thus, visitors may go swimming even for a limited amount of time where their primary beach activity was something else.

The following table presents the calculations for the lower bound "reduction factor": a/

	Poor Air ≤ 75° and/or Water < 65°	Good Air > 75° and < 79° and water ≥ 65°	Excellent Air ≥ 79° and Water ≥ 65°	Total
(a) No. of sampled days June, July and August, 1982 and 1983	55	4	26	85
(b) Proportion of days in 1982 and 1983	.647	.047	.306	1.00
(c) Proportion of predicted increase in population at risk not limited by air and water temperatures	.33	.67	1.00	--
(d) "Reduction factor" for lower bound estimate: (b) x (c)	.214	.031	.306	.551

a/ Approach suggested and data supplied by Dr. Richard Burns, Region 1, Environmental Protection Agency, Boston, MA. Categories and proportions used in (c) based on "Weather Conditions that Lure People to the Beach" by P. Rosenson and J. Havens in Maritimes, University of Rhode Island, Graduate School of Oceanography, August 1977, and "Adapted Aquatics" by The American National Red Cross, 1977, Washington, DC. Air and surface water temperature for Boston Harbor Area from NOAA, National Ocean Survey data file.

References

Cabelli, Victor J., *et al.*, 1980. *Health Effects Quality Criteria for Marine Recreational Waters*, Environmental Protection Agency, EPA-600/1-80-031.

Cabelli, V.J., A.P. Dufour, L.J. McCabe, and M.A. Levin, 1982. Swimming Associated Gastroenteritis and Water Quality. *American Journal of Epidemiology*, 115:606-616.

Hanemann, W.M., 1978. *A Methodological and Empirical Study of the Recreation Benefits from Water Quality Improvement*. PhD dissertation, Harvard University, Cambridge, MA.

Appendix D
Commercial Fisheries Benefit Computations

D.1 Demand Function Estimation

Other than the one in the study done in Maryland to predict future fisheries' supply,[a] which was discussed in the main body of the report, no other soft shelled clam demand functions were found in the literature. At present, research is being conducted at the University of Rhode Island Department of Resource Economics on developing such information about various fisheries based on National Marine Fisheries Service data. Dr. Stephen Crutchfield ran some regressions using this data to produce a range of soft shelled clam demand functions for us.[b] One of these will be described below for illustrative purposes. Because of the lack of information available to calibrate these functions properly for Massachusetts, and because these functions do not represent consumer demand in a particular market area (as discussed in the main report concerning the Maryland demand function), it was not possible to use them to compute the impacts of pollution abatement in Boston Harbor. However, since this information may be useful to others, one of these demand functions will be presented here.

The best six variable logarithmic linear model, as indicated by the maximum improvement in the R-squared statistic, found using the stepwise regression technique is as follows:

$$P = 1.876 - .076Q + .450W + .117C + .751I + .087S + .029F$$
$$(R^2 = .96)$$

---

a/ Marasco, 1975.

b/ Crutchfield, 1983.

where,

dependent variable:	P =	exvessel soft shelled clam prices (Maryland)
independent variables:	Q =	soft shelled clam landings (Maine)
	W =	wholesale prices of soft shelled clams (New York)
	C =	exvessel prices of quahogs (Rhode Island)
	I =	per capita income
	S,F =	seasonal dummy variables, summer and fall.

The stepwise regressions were run using monthly data from 1960 through 1982, where available. The regressions were set up so that Q was always included as an independent variable. Price data from Maryland and landings (harvest) data from Maine had to be used because of insufficient time series data elsewhere; extensive price and landings data were not available for Massachusetts nor did the data base used have both price and landings data for the same state. The wholesale price in New York was included as a demand shifter since New York is a large market for soft shelled clams. Quahog prices were added to represent demand for a competitive product. Per capita income is used to reflect derived demand. Seasonal dummy variables were included to account for the wide seasonal variations in demand caused by the summer tourist season. This equation produces extremely high price and income elasticities of demand. For this and the reasons mentioned above and in the main report, it was not used to compute pollution abatement benefits.

D.2 Demand Function Computations

Computations to determine the constants for the demand functions for alternative price elasticities were carried out as shown below. The following demand function was used:

$$Q = A \times P^{\alpha}$$

where, Q = consumption (bu.)
A = constant
P = price ($)
α = price elasticity

and transformed to log form:

$$\log Q = \log A + \alpha \times \log P.$$

For the Boston market for 1981, Q was set at 625,000 bu. and P at $28.45. Alternative price elasticities were selected: -.5, -1, -2 and -3. Using -1 as an example the calculations were done as follows:

$$625{,}000 = A \times (28.45)^{-1}$$

$$\log(625{,}000) = \log A - 1 \times \log(28.45)$$

$$5.7959 = \log A - 1 \times 1.4541$$

$$5.7959 = \log A - 1.4541$$

$$7.2500 = \log A.$$

To compute the new price for each price elasticity assumed and for each pollution abatement option, log A, calculated as shown above, was substituted into the demand function along with $Q + \Delta Q$, as shown below. For instance, for ΔQ = 29,603 bu., associated with the STP pollution abatement option, the computations to determine the new price were as follows (price elasticity assumed to be -1):

$$\log(Q + \Delta Q) = \log A - 1 \times \log(P - \Delta P)$$

$$5.8160 = 7.2500 - 1 \times \log(P - \Delta P)$$

$$1 \times \log(P - \Delta P) = 1.4340$$

$\log (P - \Delta P) = 1.4340$

$P - \Delta P = 27.16$

$P - 27.16 = \Delta P$

$\Delta P = 28.45 - 27.16 = 1.29.$

Total benefits for each abatement option were calculated as shown below. The change in consumer surplus is equal to the following:[a]

$\Delta CS = \Delta P \cdot Q + 1/2 (\Delta P \times \Delta Q)$

where, ΔCS = change in consumer surplus ($)
ΔP = change in price ($)
Q = initial consumption (bu.)
ΔQ = change in consumption (bu.).

Referring back to Figure 7-2 in the main body of the report, it can be seen that $\Delta P x Q$ computes the area B + C and $1/2(\Delta P \times \Delta Q)$, the area E, and that their sum in the above equation represents ΔCS equal to area B + C + E.

As an example, using the ΔP and ΔQ associated with the STP option from the above calculations, and using 16,000 bu. as a reasonable estimate of the initial consumption from Boston Harbor shellfish areas, total benefits (equal to change in consumer surplus) were estimated as follows:

$$
\begin{aligned}
\Delta CS &= \Delta P \times Q + 1/2(\Delta P \times \Delta Q) \\
&= (1.29)(16{,}000) + 1/2[(1.29)(29{,}603)] \\
&= (20{,}640) + 1/2(38{,}188) \\
&= (20{,}640) + (19{,}094) \\
&= \$39{,}734.
\end{aligned}
$$

---

[a] Note that simple geometric calculations are used here rather than integration under the curve. Even though the latter method is more accurate and correctly assumes a non-straight-line demand curve, the former is simpler, and given the magnitude of the possible error in the assumptions already made, will not adversely affect the outcome.

D.3 Supply Cost Data and Computations and Producer Surplus Computation Example

No estimates concerning producer surplus changes due to pollution abatement in Boston Harbor could be made due to lack of data. Attempts were made to develop a supply curve but were unsuccessful; these will be described below. As mentioned in the main body of the report, it is likely that change in producer surplus due to pollution abatement would be zero because the fishery is unregulated and there are no limits to prevent new firms from eventually entering and bidding away any short-run excess profits; i.e., the supply curve is probably flat in the area of interest. Despite an extensive search, no supply curves for the fishery were found in the literature. There is general agreement that is would be very hard to produce such a curve due to the extreme difficulty of modeling the biological processes affecting shellfish supply. Thus, supply for a fishery like the soft shelled clam industry is usually held to be exogenously determined.[a] This approach was taken here.

As discussed in the main report, the Boston area market for clams is supplied by Maine and Maryland as well as Massachusetts fisheries. Harvesting cost data is available for Maine (Townsend and Briggs, 1980). Costs for the typical Massachusetts digger are very similar to those for Maine.[b] Costs to diggers in restricted areas in Massachusetts, however, are higher than to others becau· of the special licensing requirements, depuration costs and additional transportation necessary to get the clams to

---

a/ From discussions with individuals at the Maryland Department of Natural Resources, the Maine Department of Marine Resources, and the Universities of Maine, Maryland and Rhode Island.

b/ Massachusetts Division of Fisheries and Wildlife estimates.

the purification plant. Prices to Maine diggers are lower than prices to Massachusetts diggers.[a] From this information, it was assumed that the supply curve for the Boston area soft shelled clam market could be represented by the curve displayed in Figure D-1. This is a stepwise supply curve in which the quantity Q_1, and price P_1, represent the quantity supplied by Maine diggers at their lower cost level. Similarly, the quantity from Q_1 to Q_2 represents the amount supplied by Massachusetts diggers from unrestricted areas and from Q_2 to Q_3 that supplied from Boston Harbor restricted areas at a higher cost. The dashed line at Q_4 and P_4 shows the decreased costs and increased quantity to the diggers that operate in Boston Harbor as a result of pollution abatement. Maryland quantities and costs are not included because the fishery there is highly mechanized and has a totally different cost structure.

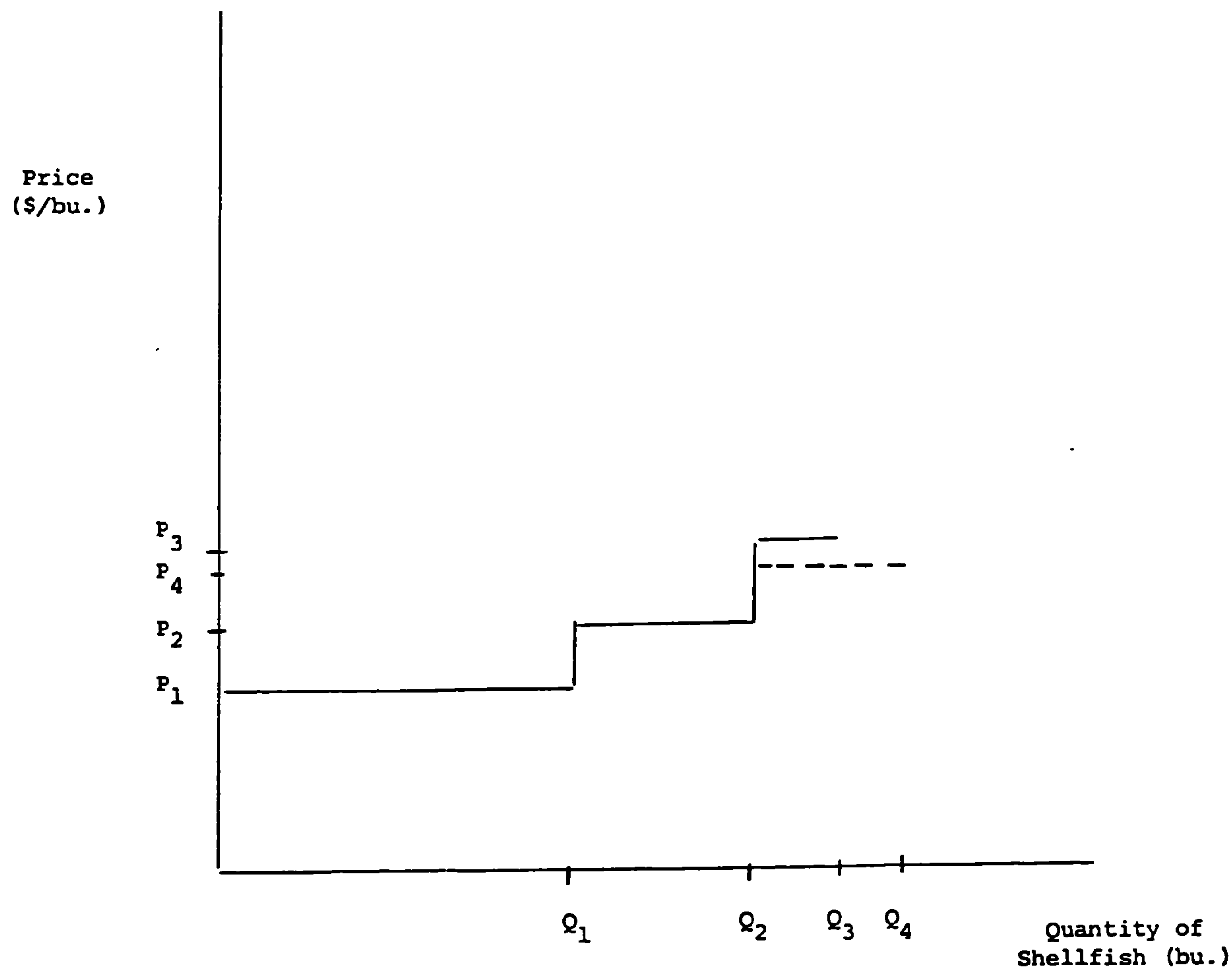
Initially, it was thought that, given the available Maine cost data, costs for Massachusetts firms could be developed for both restricted and unrestricted areas. However, with the limits on time and resources and the lack of data, it was not possible to solve two main problems. The first was to account for the fact that the firms that operate in the restricted areas are composed of a master digger and subordinate diggers unlike typical other Massachusetts and Maine firms which are single-person operations. Information was not readily available on wages and numbers of employees. The second problem, the really major one, was to determine what impact pollution abatement and the potential increased supply available in Boston Harbor would have on the harvest costs. Reasonable assumptions could be made concerning non-labor costs such as assuming decreased per unit transportation costs

---

[a] Maine Department of Natural Resources and Massachusetts Division of Fisheries and Wildlife data.

Figure D-1.

Assumed Shape of Supply Curve for Boston Area Soft Shelled Clam Market.



since more clams could be hauled per daily trip to the purification plant. However, it was very difficult to estimate the impacts on return to the master digger or on numbers of subordinates that would be hired. Therefore, it was not possible to complete this representation of the supply curve for the Boston Harbor market so that it could be combined with the previously estimated demand curves to compute changes in producer surplus. It was thought, however, that the preliminary computations that were completed might be useful to others and should be presented in an appendix. The following tables and discussion show the data used and computations that were made in order to estimate soft shelled clam harvest costs for both unrestricted areas in Maine and restricted and unrestricted areas in Massachusetts.

Table D-1 shows annual 1978 costs for a typical Maine clam digging firm, a one-person operation, developed by Townsend and Briggs (1980). In Table D-2, these costs are updated to 1980 dollars for Massachusetts diggers who operate in unrestricted areas. Updated costs for Maine firms are also shown at the bottom of this table.

Tables D-3 through D-6 show the computation of nonlabor costs for Massachusetts shellfishing firms operating in Boston Harbor restricted areas. Because it was not possible to develop costs for a typical firm operating in Boston Harbor restricted areas due to the lack of information regarding numbers of subordinate diggers employed and their wage rates, i. was decided that costs should be developed on a per bushel basis. Table D-3 shows per bushel costs divided into four categories for computation purposes. Nonspecialized items are those for restricted firms that correspond to the items included in the single-person unrestricted firms shown in Table D-2. Specialized items are those that are required by either

Table D-1. Cost Data for a Typical Maine Clam Digging Firm, 1978 $

Capital Costs:

Items	1978 Cost	Life	Annual Depreciation
Car (1/2 cost of new car)	2500	4	625
Boat	1200	10	120
Trailer	600	10	60
Outboard Motor	1000	4	250
SUBTOTAL:			1055

Direct Expenses:

Items	1978 Unit Cost	No. of Units	Annual Cost
Fuel, Car	.80/gal	55.6	44
Fuel, Boat	.80/gal	7.5	6
Auto Maintenance			200
Boat Maintenance			200
License			10
Insurance			100
Boots & Gloves			28
Hods	12	2	24
Clam Hoe		1	15
SUBTOTAL:			627
TOTAL:			1682
Owner Operator Income:			2234

Source: Townsend and Briggs, 1980.

Notes:

Volumes: 210 bushels/year @ $18.65.

Gross Revenue: $3916.50.

Employment: one.

Operates: 5 months per year.

Table D-2. Costs for a Typical Massachusetts Shellfishing Firm Operating in Unrestricted Areas, 1980$

Capital Costs:

Items	1978 Cost	Adjustment Factor[a]	1980 Cost	Life	Annual Depreciation [b]
Vehicle (1/2 cost of new car; 50% devoted to clamming)	2500	1.31	3275	4	818.75
Boat	1200	1.31	1572	10	157.2
Trailer	600	1.31	786	10	78.6
Outboard Motor	1000	1.31	1310	4	327.5
SUBTOTAL:					1382.05

Direct Expenses:

Items	1978 Price	Adjustment Factor[a]	1980 Price	Quantity	Total
Fuel, Car	.80/gal	1.31	1.05	55.6 (1,000 mi/yr @ 18 mi/gal)	58.4
Fuel, Boat	.80/gal	1.31	1.05	7.5 (300 mi/yr @ 40 mi/gal)	7.9
Auto Maint.	200	1.31	262	1	262
Boat Maint.	200	1.31	262	1	262
License	-	-	30	1	30
Insurance	100	1.31	131	1	131
Boots & Gloves	28	1.31	36.68	1	36.68
Hods	12	1.31	15.72	2	31.44
Clam Hoe	15	1.31	19.65	1	19.65
SUBTOTAL:					839.07
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					2221.12

[Similarly Updated Annual Costs for Maine Firms (1980 $) = 2203.05]

Source: Meta Systems estimates based on Townsend and Briggs, 1980 and Williams, (no date).

[a] CPI Boston.

[b] Assumes straight-line depreciation.

Notes:

210 bushels/yr.; average harvest.

Operates 5 mo./yr.; 100 days/yr.; 5 days/wk.

120 tides per year; 1.75 bu./tide/digger.

Table D-3. Per Bushel Nonlabor Harvest Costs for Boston Harbor Restricted Areas

Cost Categories	Cost/Bushel 1980 $
Nonspecialized Items	5.01
Specialized Items - Subordinate Diggers	3.47
Specialized Items - Master Diggers	6.18
Depuration Costs	2.00
TOTAL:	16.66

Notes:

Depuration Costs: $1.00/rack; 2 rack/bu.; $2/bu.

Table D-4. Per Bushel Costs for Nonspecialized Items[a]

Capital Costs: Items	1978 Cost	Adjustment Factor[b]	1980 Cost	Life	Annual Depreciation[c]
Boat	1200	1.31	1572	10	157.2
Trailer	600	1.31	786	10	78.6
Outboard Motor	1000	1.31	1310	4	327.5
TOTAL:					563.3

Direct Expenses: Items	1978 Price	Adjustment Factor[b]	1980 Price	Quantity	Total
Fuel, Boat	.80/gal	1.31	1.05	7.5 (300 mi/yr @ 40 mi/gal)	7.9
Boat Maint.	200	1.31	262	1	262
Insurance	100	1.31	131	1	131
Boots & Gloves	28	1.31	36.68	1	36.68
Hods	12	1.31	15.72	2	31.44
Clam Hoe	15	1.31	19.65	1	19.65
TOTAL:					488.67
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					1051.97

= $5.01/bu. @ 210 bu./yr. (from Maine cost data)

a/ Based on costs estimated for Maine diggers for 1978, Townsend and Briggs, 1980.

b/ CPI Boston.

c/ Straight-line depreciation assumed.

Table D-5. Per Bushel Specialized Costs for Subordinate Diggers

Capital Costs:					
Items	1978 Cost	Adjustment Factor[a/]	1980 Cost	Life	Annual Depreciation
Car (50%)	2500	1.31	3275	4	818.75
Direct Expenses:					
Items	1978 Price	Adjustment Factor [a/]	1980 Price	Quantity	Total
Fuel, Car	.80/gal	1.31	1.05	55.6	58.4
Auto Maint.	200	1.31	262	1	262
License	-	-	30	1	30
TOTAL:					350.4
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					1169.15

= $1169.15/subordinate digger x 49 diggers[b/] ÷ 16,500 bu. = $3.47/bu.

a/ CPI Boston

b/ Estimated average annual number of subordinate diggers = 16,500 bu./yr. total harvest ÷ 210 bu./digger/yr. = 79 diggers ÷ 30 master diggers = 49 subordinate diggers. This number may be an overestimate because restricted flats may tend to have more clams/acre and therefore the harvest may be greater per person than indicated in the Maine data. However, personnel must be used to transport clams to the purification plant which would increase the employee/bushel ratio.

Table D-6. Per Bushel Specialized Costs for Master Diggers

Capital Costs:					
Items	1978 Cost	Adjustment Factor	1980 Cost	Life	Annual Depreciation
Truck	5500	1.31	7205	4	1801.25
Racks	-	-	$10 x 33 = 330	3	110
Surety Bond	-	-	500	20	93.5[a]
SUBTOTAL:					2004.75

Direct Expenses:					
Items	1978 Price	Adjustment Factor	1980 Price	Quantity	Total
Fuel, Truck	.80/gal	1.31	1.05	611.2[b]	641.76
Truck Maint.	500	1.31	655	1	655
License	-	-	100	1	100
SUBTOTAL:					1396.76
ANNUAL CAPITAL COSTS PLUS DIRECT EXPENSES:					3401.51

= $3401.51/master digger x 30 master diggers ÷ 16,500 bu. = $6.18/bu.

[a] Used capital recovery factor = .187 (20 yr. life, 8% interest).

[b] 611.2 = 55.6 (1000 mi/yr @ 18 mi/gal) + 555.6(10,000 mi/yr @ 18 mi/gal).

Notes:

Operates 5 mo./yr.; 5 days/week; 100 days/yr.
Approximately 16,500 bu./yr. depurated from Boston Harbor; 30 master diggers operate in Boston Harbor; 550 bushels/master digger/yr.; 5.5 bushels/day/master digger.

2 racks/bushel; 11 racks/day x 3 days = 33 racks/master digger.

Approximately 50 mi. from harvest area to depuration plant;
100 mi./day x 100 days/yr. = 10,000 mi./yr. to depuration plant.

the master or subordinate digger because they operate in restricted areas. Depuration costs are the per bushel costs for the clams to be handled by the purification plant. The development of nonspecialized costs is shown in Table D-4. Specialized costs are computed for subordinate diggers in Table D-5 and for master diggers in Table D-6. These computations assume that the annual harvest from Boston Harbor restricted areas is 16,500 bushels,[a/] that there are 30 master diggers[a/] operating in the harbor and that each digger harvests approximately 210 bushels annually.[b/]

Changes in per bushel costs due to pollution abatement are shown in Table D-7. It is assumed, for illustration purposes, that the fishery is restricted and therefore no additional firms (master diggers) can enter. More subordinate diggers would be hired, however. The additional yield from the restricted areas was a preliminary figure later changed in the main body of the report (see Table 7-2). To compute total number of diggers, the same annual harvest rate was assumed as for Table D-3. The main impact of the pollution abatement was assumed to be an increased annual harvest which would allow master diggers to transport approximately four times as many bushels per daily trip to the purification plant as without abatement. The purification plant is currently undergoing expansion which will allow it to handle larger numbers of shellfish per day.

Table D-8 compares available price data with the nonlabor cost data computed for Maine and Massachusetts. Theoretically, the difference between the price and the nonlabor cost should reflect the income to the firm owner

---

a/ Division of Marine Fisheries estimates. The 16,500 was later revised to 16,000 in the main report.

b/ Townsend and Briggs, 1980.

Table D-7. Changes in Per Bushel Nonlabor Costs for Boston Harbor Restricted Areas Due to Pollution Abatement

	Cost Per Bushel, 1980 $	
Cost Categories	Without Abatement	With Abatement
Nonspecialized Items	5.01	5.01
Specialized Items - Subordinate Diggers	3.47	5.03
- Master Diggers	6.18	1.69
Depuration Costs	2.00	2.00
TOTALS:	16.66	13.73
Change in Per Bushel Cost	-2.93	

Notes:

Annual yield: 16,500 + 49,928 [a] = 66,428 bu./yr.

66,428 bu./yr. ÷ 30 master diggers [b] = 2,214 bu./master digger/yr.; 22.1 bu./day (4 times as many as before abatement)

66,428 bu./yr. ÷ 210 bu./digger [c] = 316 diggers

÷ 30 master diggers = 286 subordinate diggers

Costs for nonspecialized items - no change.

Specialized costs - subordinate diggers:

$1169.15/subordinate digger x 286 diggers ÷ 66,428 bu. = $5.03/bu.

Specialized costs - master diggers:

Racks: 2 racks/bu.; 44.2 racks/day x 3 days = 132.6 racks/master digger;

132.6 racks x $10 = $1326 ÷ 3 yr. life = $442.

Cost per master digger = $3733.51 x 30 master diggers ÷ 66,428 bu. = 1.69/bu.

Depuration costs - no change.

---

a/ Assuming additional yield of 49,928 bu./yr., revised in main report.

b/ Assuming restricted fishery - no change in number of master diggers.

c/ Townsend and Briggs, 1980.

Table D-8. Comparison of Nonlabor Costs and Prices

Location and Year	Nonlabor Cost/Bu.	Inflated Price/Bu.[a]	Price/Bu.
Maine, 1978 $	8.01[b]	n.a.	18.65[b]
Maine, 1980 $	10.49	24.43	22.65[c]
Massachusetts, 1980 $			
Unrestricted Areas	10.57	24.43	28.00[d]
Restricted Areas			
Before Abatement	16.66	n.a.	28.00[d]
After Abatement	13.73	n.a.	28.00[d]

a/ CPI used to inflate 1978 Maine price to 1980 $.
b/ Townsend and Briggs, 1980.
c/ Maine Department of Marine Resources, Clam Production and Value, 1887-1982.
d/ Resources for Cape Ann, 1982.

n.a. = Not applicable.

and employees. However, there is not enough cost and price information available to address this question adequately.

If the cost computations discussed above formed a reasonable basis on which to estimate shifts in the supply curve, then they could be used to calculate change in producer surplus due to pollution abatement. This is simply not the case because of data inadequacies. For illustration purposes, however, we could assume that they are acceptable and that the change in per bushel cost shown in Table D-7 is a reasonable estimate of per unit supply cost changes due to pollution abatement. Change in producer surplus would then be computed as follows:

$$\begin{aligned} \Delta PS &= Profits_1 - Profits_0 \\ &= (P_1Q_1 - C_1Q_1) - (P_0Q_0 - C_0Q_0) \\ &= Q_1\ (P_1 - C_1) - Q_0\ (P_0 - C_0) \end{aligned}$$

where,

$Profits_0$ = initial profits = $P_0Q_0 - C_0Q_0$
$Profits_1$ = new profits = $P_1Q_1 - C_1Q_1$
ΔPS = change in producer surplus ($)
P_0 = initial price ($)
P_1 = new price ($)
Q_0 = initial quantity harvested (bu.)
Q_1 = new quantity harvested (bu.)
C_0 = initial cost ($)
C_1 = new cost ($)

As an example, if the preliminary change in yield and initial quantity harvested (later revised) used in Table D-7 and the initial price of $28.00/bu. (also revised) and cost of $16.66/bu. used in Table D-8 were assumed and if a price change of -$1.99 was also assumed (this is also a preliminary estimate that was made using the preliminary change in yield and one of the initial demand functions considered, later revised in the main report), then the change in producer surplus would be computed as follows:

$$\Delta PS = \text{Profits}_1 - \text{Profits}_0$$
$$= Q_1 (P_1 - C_1) - Q_0 (P_0 - C_0)$$
$$= (66{,}428)(26.01 - 13.73) - (16{,}500)(28.00 - 16.66)$$
$$= (66{,}428)(12.28) - (16{,}500)(11.34)$$
$$= 815{,}736 - 187{,}110$$
$$= \$628{,}626.$$

It should be emphasized that this number is only hypothetical. As discussed earlier, it was thought best to omit computation of producer surplus changes in the main report because of lack of information to specify supply curve shifts and because of the likelihood that these changes would be zero due to the lack of regulation of the fishery.

References

Crutchfield, Stephen R., February 1983. "Soft Clam Exvessel Demand Functions and Clam Fishery Data," unpublished data, Department of Resource Economics, University of Rhode Island, Kingston, RI.

Marasco, Richard J., May 1975. An Analysis of Future Demands, Supplies, Prices and Needs for Fishery Resources of the Chesapeake Bay, MP 868, Agricultural Experiment Station, University of Maryland, College Park, Maryland.

Resources for Cape Ann, April 1982. The Costs of Pollution: The Shellfish Industry and the Effects of Coastal Water Pollution, Massachusetts Audubon Society.

Townsend, Ralph and Hugh Briggs, September 1980. Some Estimates of Harvesting and Processing Costs for Maine's Marine Industries, technical report, Department of Economics, University of Maine.

Williams, Doug, (no date). "Data and Procedures Used to Estimate Technical Coefficients for the Clam/Worm Sector," unpublished paper, Department of Agricultural and Resource Economics, University of Maine.

Appendix E

Charles River Boating Benefits

Additional Boating Days per Year on the Charles River

Boating Days	=	(1) Δ BP	x	(2) Current Boating Days
52,810	=	0.03142		1,680,800 High
5,750	=	0.03142		183,000 Low

(1) $BP = 0.38485\ (\Delta W)^{(a)} + 0.03142\ (\Delta FPS)^{(b)}$

$0.03142 = (0.3845)\ (0) + 0.03142\ (1)$

Source: Davidson P., G. Adams and J. Seneca, 1966. The Social Value of Water Recreational Facilities from an Improvement in Water Quality: the Delaware Estuary. Water Research, Allen Kneese and Stephen C. Smith, eds. Baltimore: Johns Hopkins University Press for Resources for the Future.

(a) ΔW = acreage of recreational water available per capita.

= 0, because currently all 675 acres of the Charles River in the Basin planning area are boatable.

(b) ΔFPS = change in recreational facility rating.

= 1 (assumed).

(2) Current Boating Days

Boating Days	=	(a) Portion of Population Boating on Charles	x	(b) No. days per Boater	x	(c) Boating Population
High = 1,680,800	=	.40		5.5		764,000

(a), (b) Source: Recreation studies (see Appendix B).

(c) Boating population equals population of towns bordering or very near to the Charles River in the planning area.

Cambridge	95,000
Watertown	34,000
Newton	83,000
Brookline	55,000
3/4 Boston	420,000
Somerville	77,000
Total	764,000

Source: 1980 U.S. Census.

				(i)		(ii)
Low	=	Boating Days	=	Family visitor days per season	x	Family number
Low	=	183,000	=	68,000	x	2.69

(i) Source: Calculations based on information in Binkley and Hanemann, 1975, The Recreation Benefits of Water Quality Improvement, prepared for Environmental Protection Agency, Washington, DC. 5.6 percent of all reported 850 visits for the summer season were boating-related activities. Sample was statistically representative of 0.07 percent of the SMSA population.

Therefore 850 = 1,214,286 family visits, of which 5.6 percent, or 68,000 are family visitor days.

(ii) Source: 1980 U.S. Census.